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Coherent Network Primary Reference Time Clocks (cnPRTC) Simulation and Test Results

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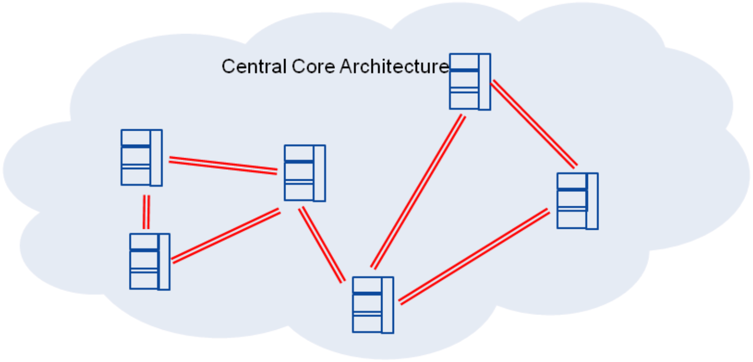
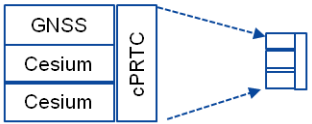
Coherent Network PRTC Overview



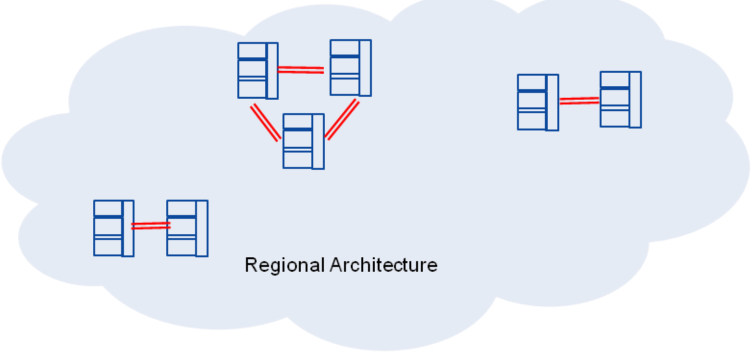


Primary Objectives

- Reliability: Immune from local jamming or outages

- Autonomy: Cesium Ensemble Sustained Timescale (definition of second) GNSS connect non-critical.

- Coherency: 30ns coordination assures overall PRTC budget



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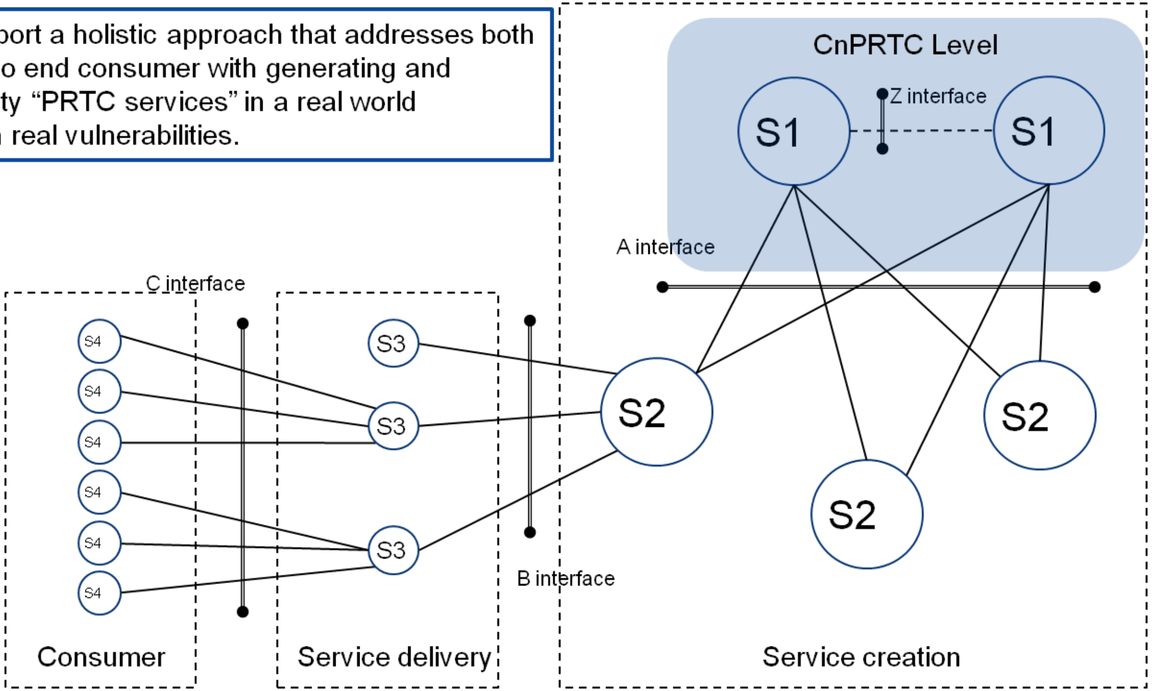
Coherent Time/Frequency Functional Architecture

Architecture support a holistic approach that addresses both service delivery to end consumer with generating and maintaining quality "PRTC services" in a real world environment with real vulnerabilities.

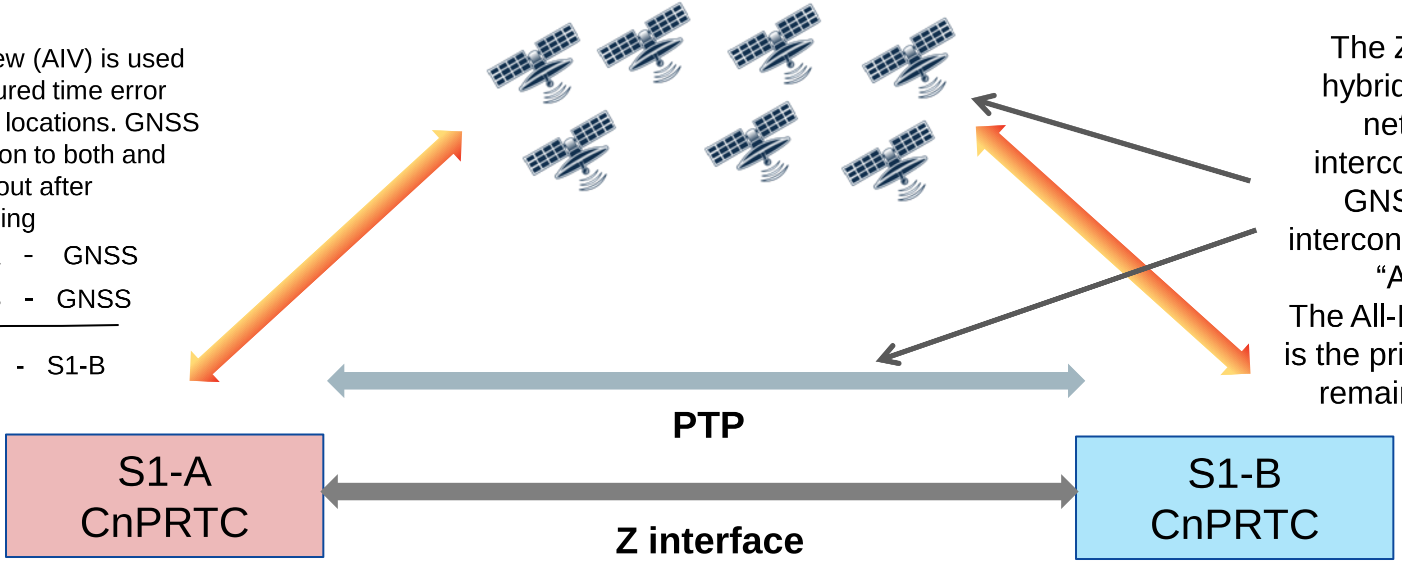


S1: Coherent cnPRTC level– Ensembling timing source, Perpetual Coherent Time Traceability
S2: Hierarchical PRTC level– Redundant Traceable A interfaces from S1 extend service creation from core.
S3: Sync delivery – delivers sync source to clients (PTP and associated path aware standards plus frequency sync e.g. Sync E)
S4: Sync edge/client – consumes the services

The "Z Interface"

All-In-View (AIV) is used to measured time error between locations. GNSS is common to both and cancels out after differencing

$$
\begin{array}{r l}
 & \text{S1-A} - \text{GNSS} \\
- & \text{S1-B} - \text{GNSS} \\
\hline
 & \text{S1-A} - \text{S1-B}
\end{array}
$$

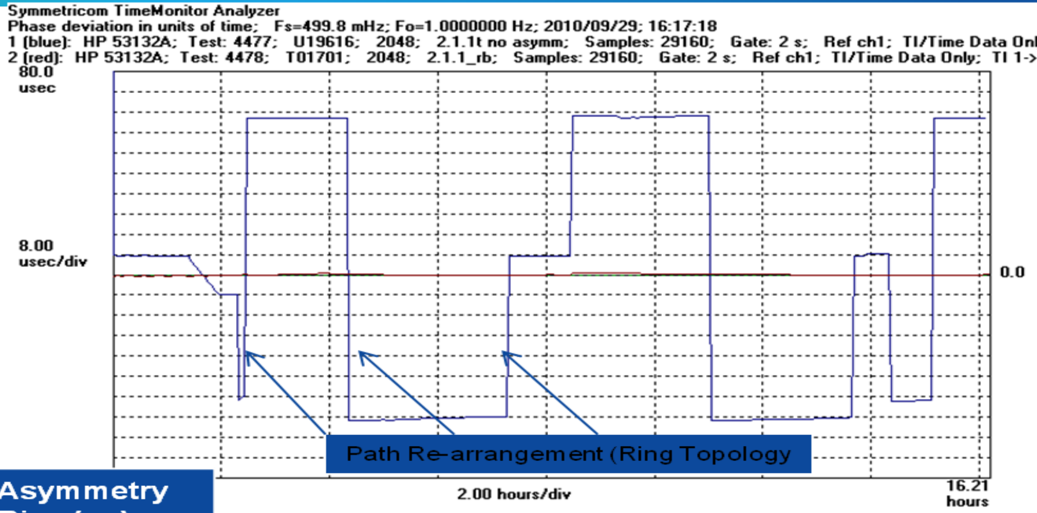


The Z interface is a hybrid of both a PTP network based interconnect as well a GNSS differential interconnect based on an “All-In-View “

The All-In-View approach is the primary focus of the remainder of this talk

Z interface combined strength of PTP and GNSS

- **Asymmetry Correction Algorithm supplies external correction factor defined in 1588 standard.**
- **Algorithm learns asymmetries to prevent in-accurate time output**
- **Addressed both PTP and GNSS potential vulnerabilities**



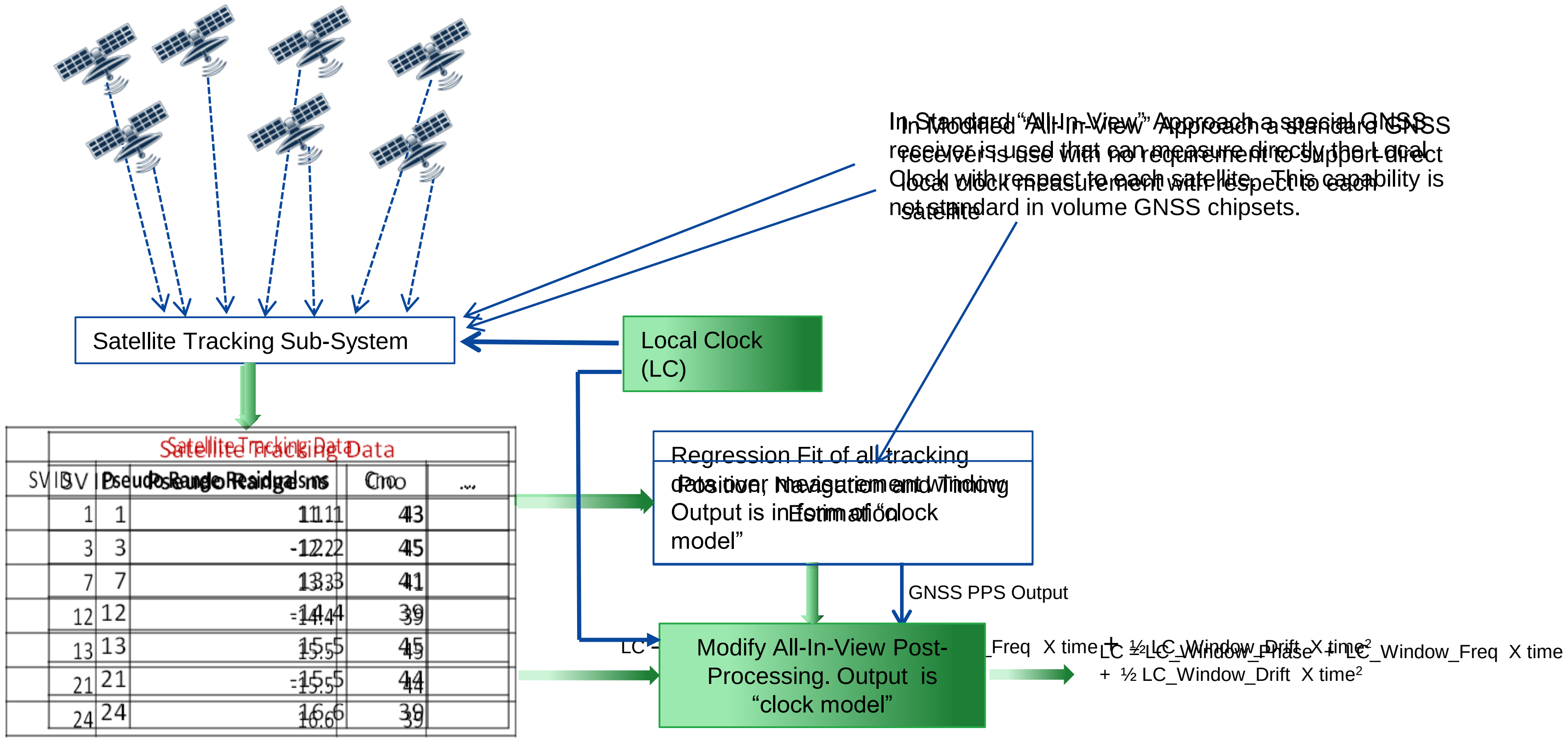
Path Signature			Asymmetry Bias (ns)
Round Trip Delay	Observed Bias	Secondary Path Parameters	
Path Signature A			AAA.A
Path Signature B			BBB.B
Path Signature C			CCC.C

Performance on Customer Network test environment:

BLUE: PPS Performance without Asymmetry correction.

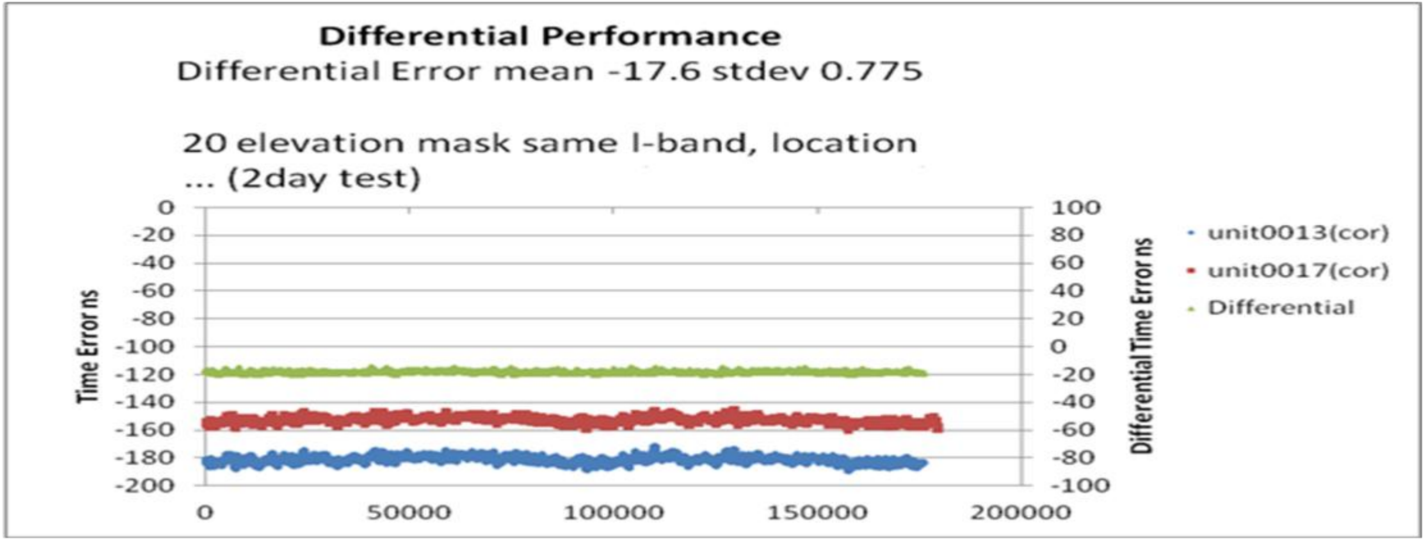
RED: PPS Performance with Asymmetry correction.

"All-In-View Approach"



Modified All-In-View (20 degree Mask) – Baseline Common L-Band Antenna

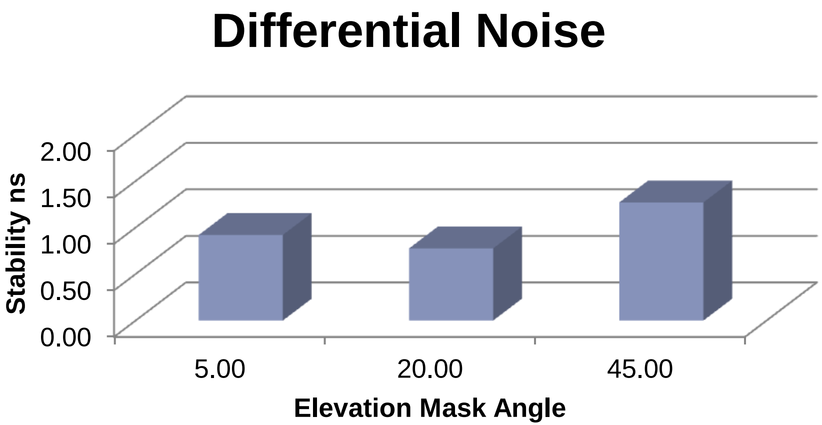
Results show the tight correlation between the two units (notice common tracking between red and green plots). The difference is shown in the green graph. Note that the residual time noise is **less than 1 ns** (775 ps rms). The small time bias (-17.6ns) is accounted for based on known delay biases in test configuration. In subsequent slides the proper calibration is applied.



Baseline Test Different Elevation Mask Angles

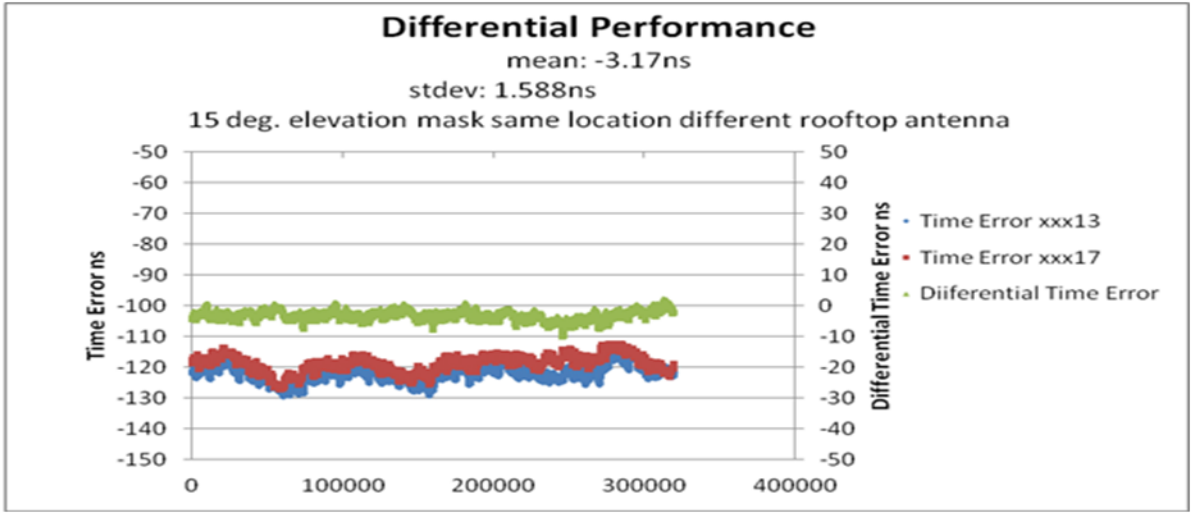
The common L-band antenna baseline test is repeated with different elevation mask angle limits set to constrain the constellation set. The test results show several effects:

1) The overall impact of elevation mask angle is relatively modest for sensible selections. Note that the residual time noise is under 1 ns from 5 degrees to 45 degrees.
2) There is a broad optimum for mask angle. The 20 degree elevation test results are modestly better than the two extreme cases.
3) Heuristically higher elevation masks reduce non-common effects associated with low elevations satellites at the expense of less satellites to be included in the over determined clock model.



Modified All-In-View 15 degree elevation Two L-Band Antenna Co-located on common rooftop.

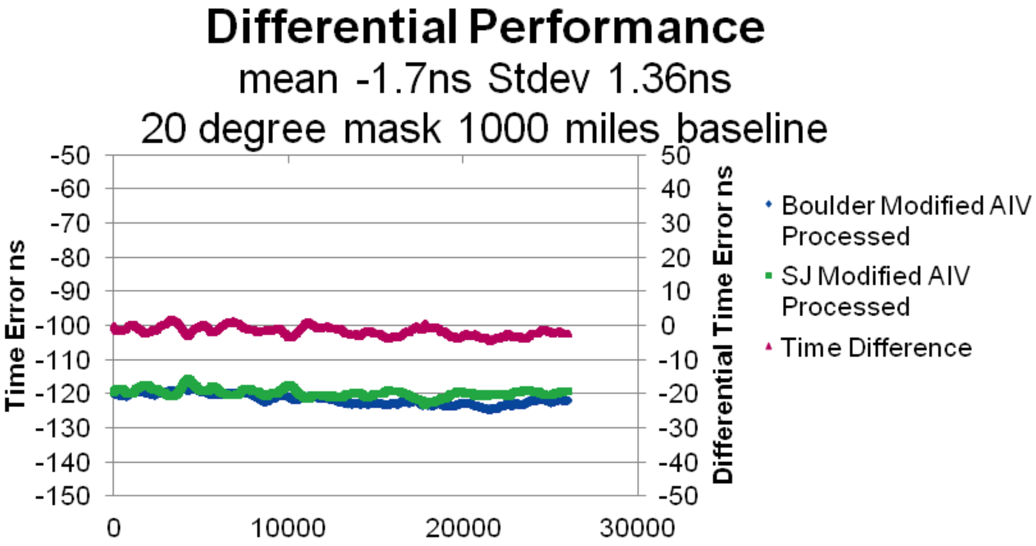
Long Weekend Test with two different antennas in same location.
Note small increase in residual time noise (still small 1.588ns rms).



Modified All-In-View 20 degree elevation Two L-Band Antenna 1000 miles apart.

In this test the two modified all-in-view system were configured with one in our San Jose Lab and the other in our Boulder Lap (nominally 1000 miles apart). We utilized our calibrated house reference time scale systems in both facilities as the local reference clocks. The test results:

1) At this baseline distance the “deterministic correlation” of both individual measurements (green and blue) is replaced by the expected all-in-view “melting pot” statistical correlation.
2) The observed average time difference is a very respectable 1.7 ns with a time error noise of 1.36ns. Visually the time difference error is less than 5ns.



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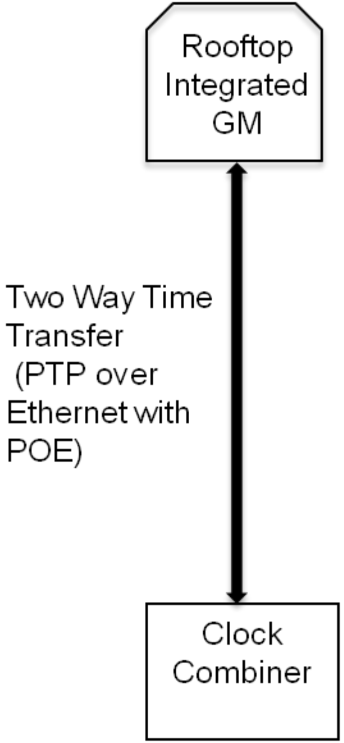
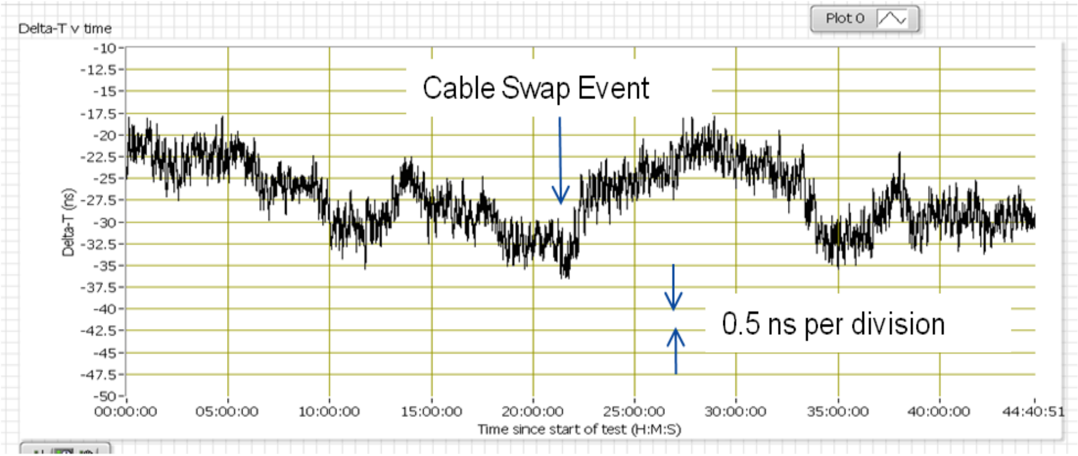
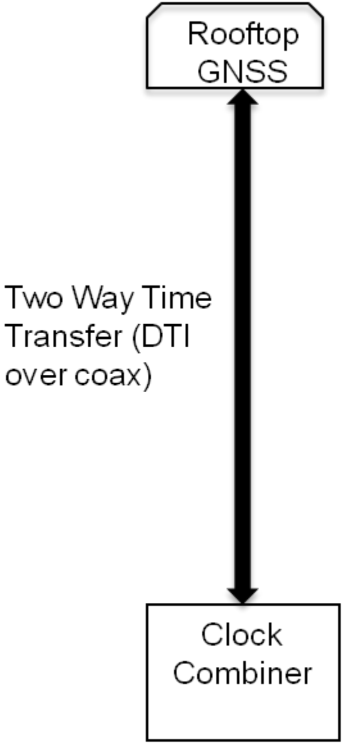
TWTT Continual Automatic Antenna Cable Delay Calibration



Precision of “Z interface” ensures with an Antenna that Integrates the GNSS receiver with a Two-Way Protocol. The calibration is done at the factory and is independent of cable length. L-Band antenna with cable is vulnerable to tampering especially in public accessible locations.



Cable Delay Bias Mitigation Test Results (200ft and 700ft cable swap)



Summary

- Z interface addresses operating a phase/time service in a real-world environment with vulnerabilities such as GNSS jamming and PTP asymmetry.

- Modified All-In-View leverage high volume GNSS support differential time measurement to 5ns accuracy

- Integrate Antenna with Two-Way protocols such as PTP address operational time accuracy concerns