Extreme Sensitivity Indoor GPS Providing High Accuracy Time

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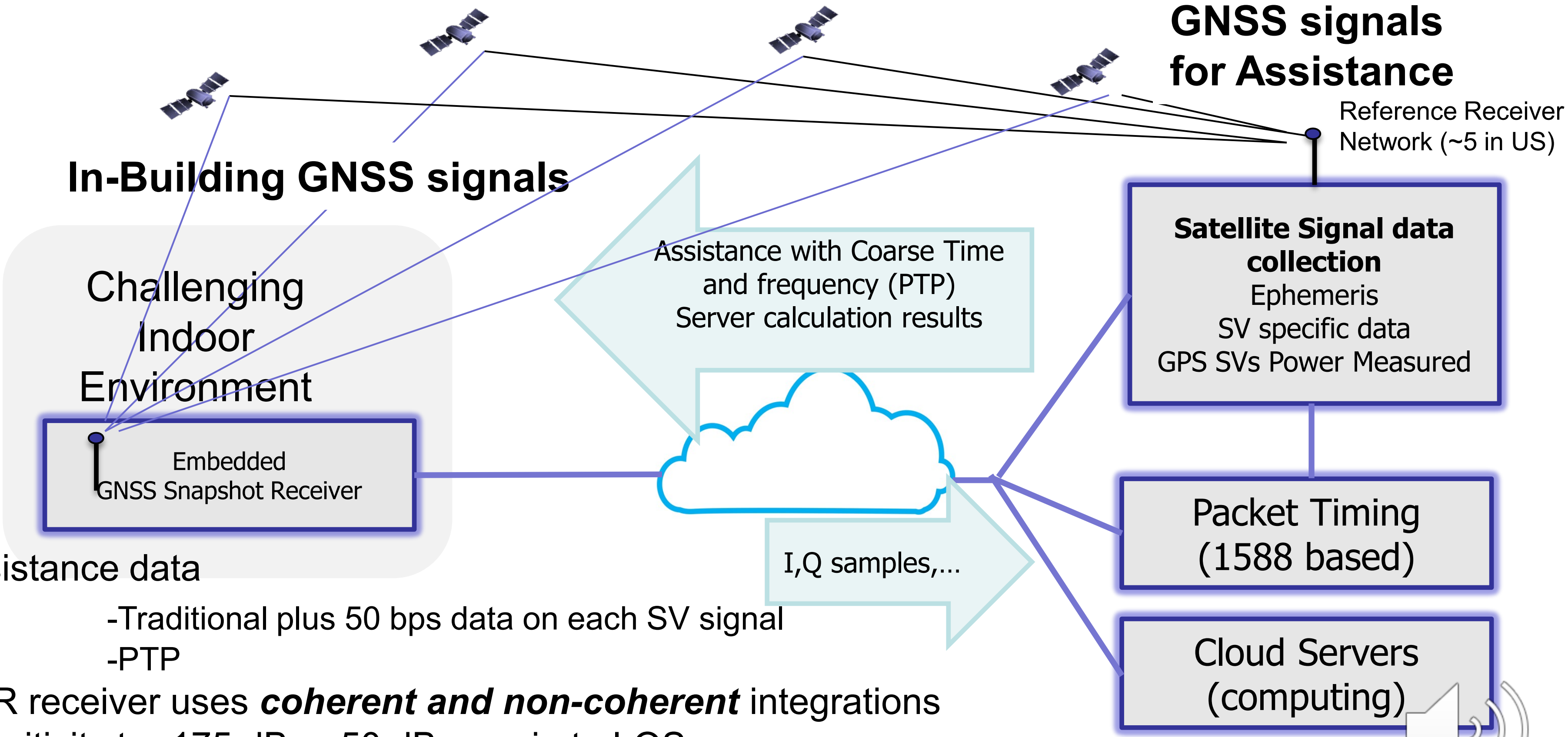
GPS Systems

- Chicken or the egg (GPS works best if it knows where it is and what time it is)
- Unassisted GPS (U-GPS)
  - Provides large time, location and frequency search ranges - giving up sensitivity
  - Indoor U-GPS receivers require costly outdoor antenna installation and cable routing
- Cellular Assisted C-GPS
  - Gets moderate time and good location assistance from the cellular system
  - Some performance indoors
  - Tracking sensitivity is better than acquisition
- Enhanced Internet Assisted GPS (EIA-GPS) with SDR
  - Gets more assistance data

Enhanced Internet Assisted GPS System



Assistance data

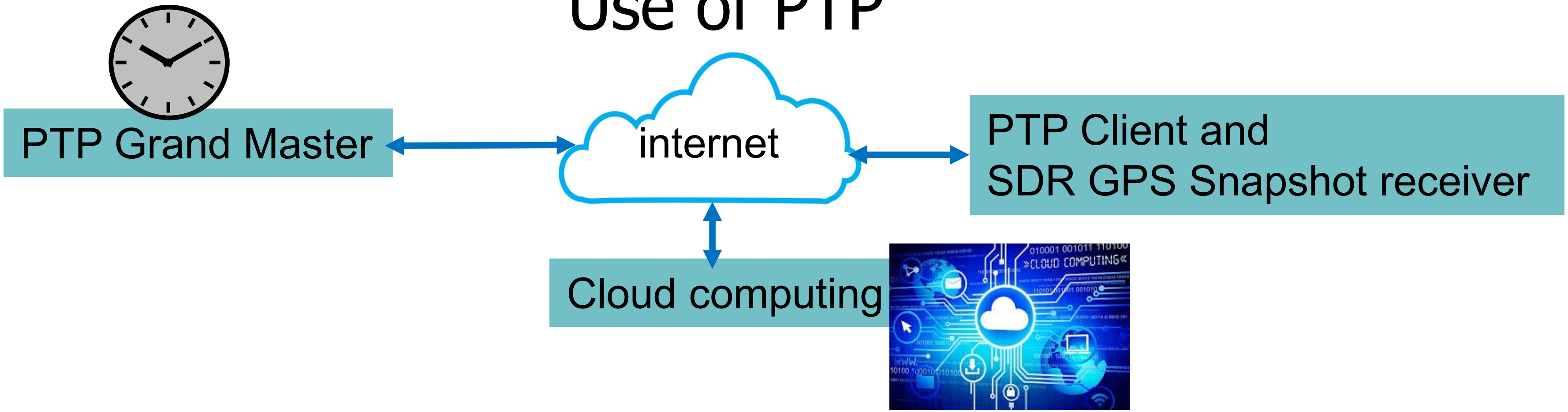
-Traditional plus 50 bps data on each SV signal

-PTP

SDR receiver uses ***coherent and non-coherent*** integrations

Sensitivity to -175 dBm, 50 dB margin to LOS power

Use of PTP



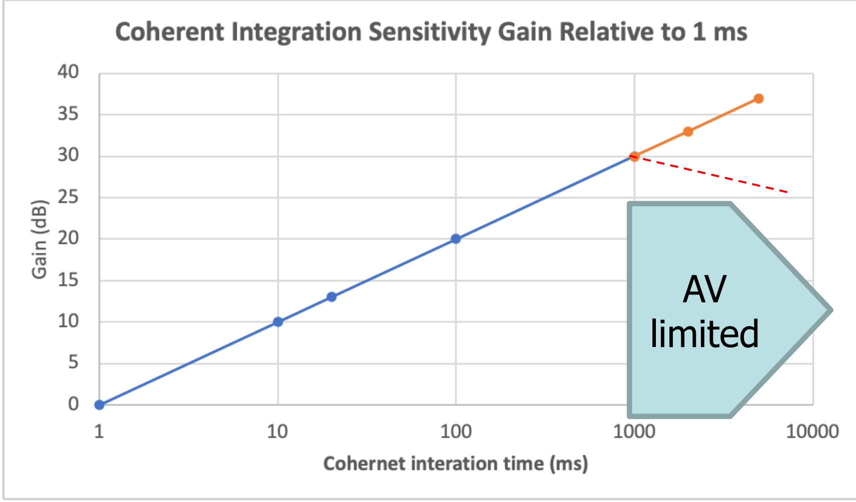
- PTP has been tried for 3GPP sync to 1.5 μsec
- SDR snapshot Rx acquires time and frequency without PTP aware networks
- PTP provides sufficient time and frequency
  - PTP primes the EIA-GPS TOD (PPS phase)
  - PTP primes the EIA-GPS TCXO and PPS frequency (PPS rate)
  - Completes PTP session in as little as 30 seconds
- Cloud computing expands time uncertainty to > 5 ms
- EIA_GPS acquires GPS signals in one SNAPSHOT measurement
  - PTP is disengaged
  - GPS time tracking is kept locally in the Client

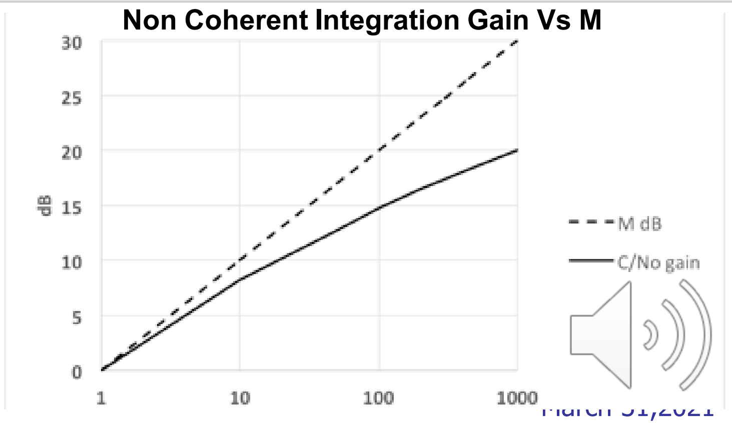
Snapshot Receiver Gain

- **Coherent integration of 1 to 2 seconds**
  - CI limited by TCXO Alan Variance
  - Gain =linear with CI time
  - 1 sec CI yields 30 dB gain over one 1 ms epoch

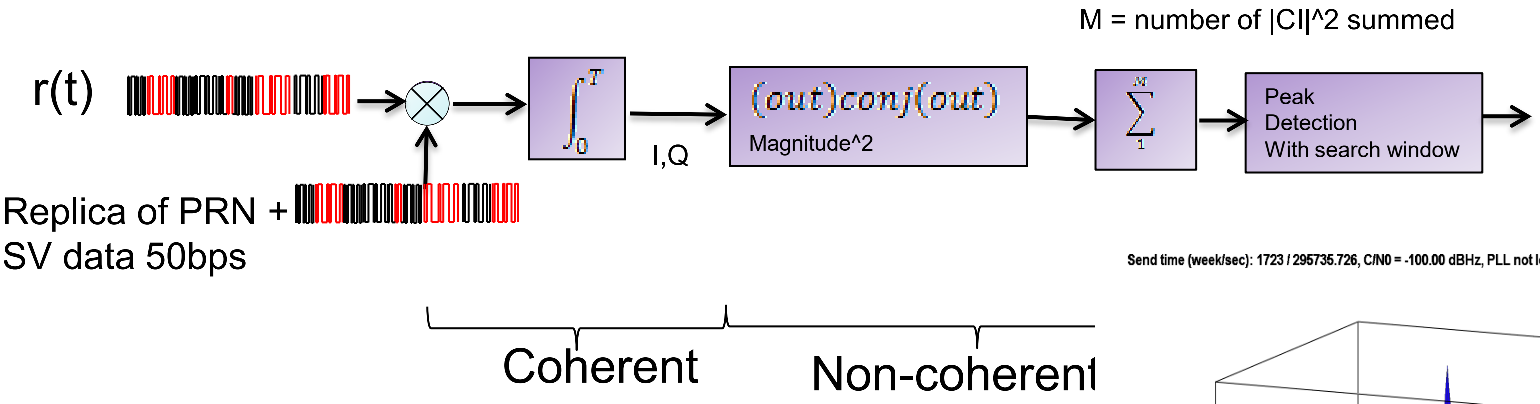
- **Non-coherent integration does not follow a linear relationship at low C/No**
  - Gain for 300 NCI(M) = 17dB at detection threshold ,linear would be 25 dB

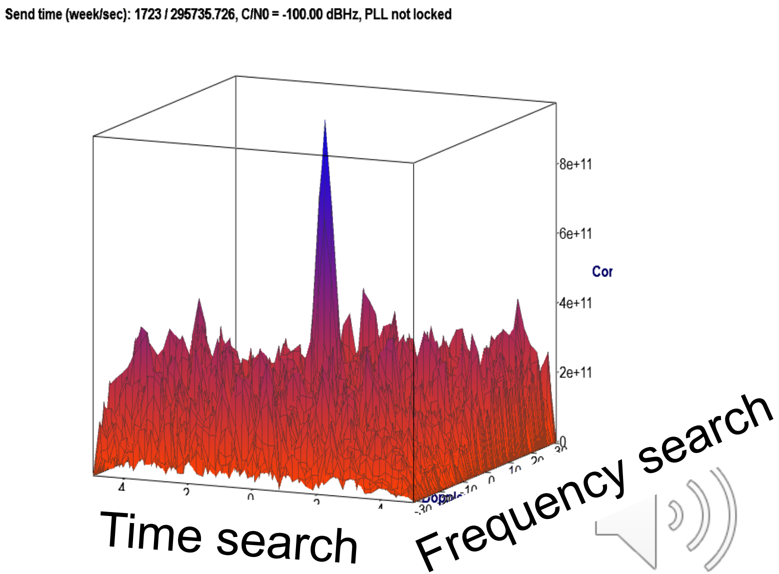
- **Lesson**
  - Increase CI until AV starts degrading performance
  - Increase NCIs (M) until loss from linearity is intolerable





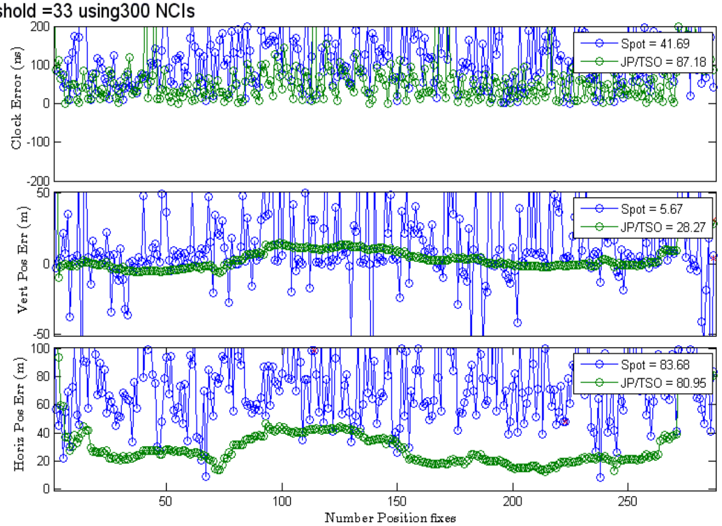
GPS Receiver Coherent and Non-Coherent Processing [1]





- All GPS receivers generate a PRN code replica
- Correlation search over time based on expected range error from PTP PPS time reference
- Correlation search over frequency based on expected range from the TCXO
- Sensitivity -175 dBm

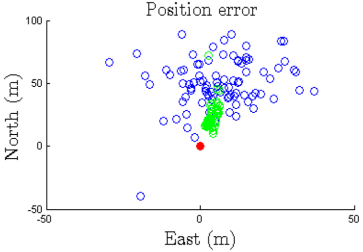
Performance in CU Engineering Center Complex: Lower Basement 3.5m below grade

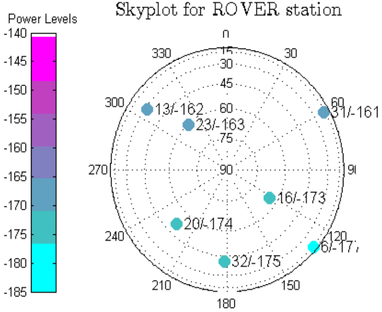


Blu-Spot fixes

Grn-Joint fixes

	Real Time-JP	Post Process
East	4.7 m	
North	23.6 m	
Horizontal	24.1 m	19m
Vertical	1.6 m	0.5 m
Time corrections		**34 ns rms**





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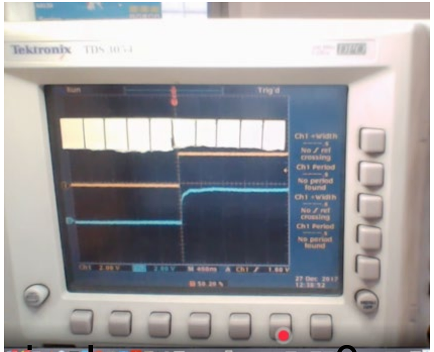
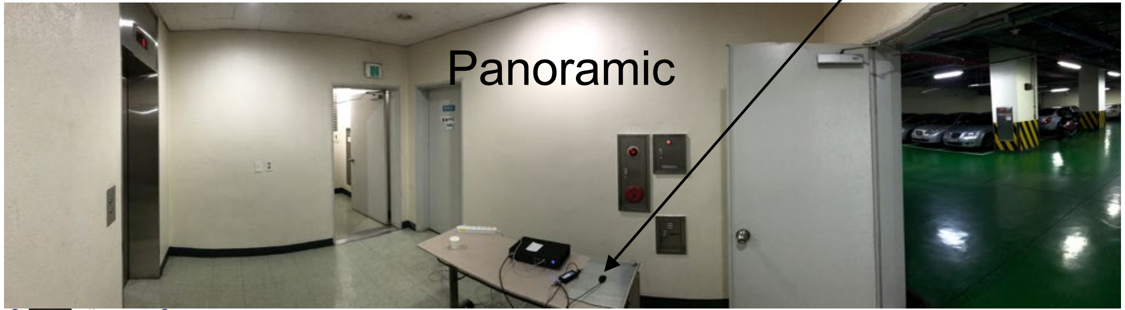
Building in Bundang-Basement, Korea

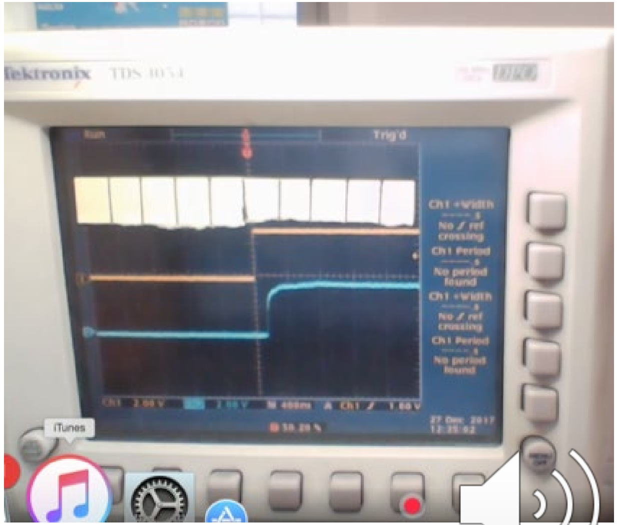
8 Story Building



Typical error near 0 ns

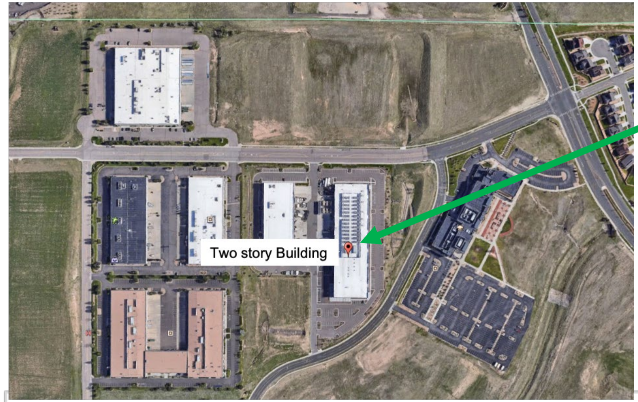
antenna





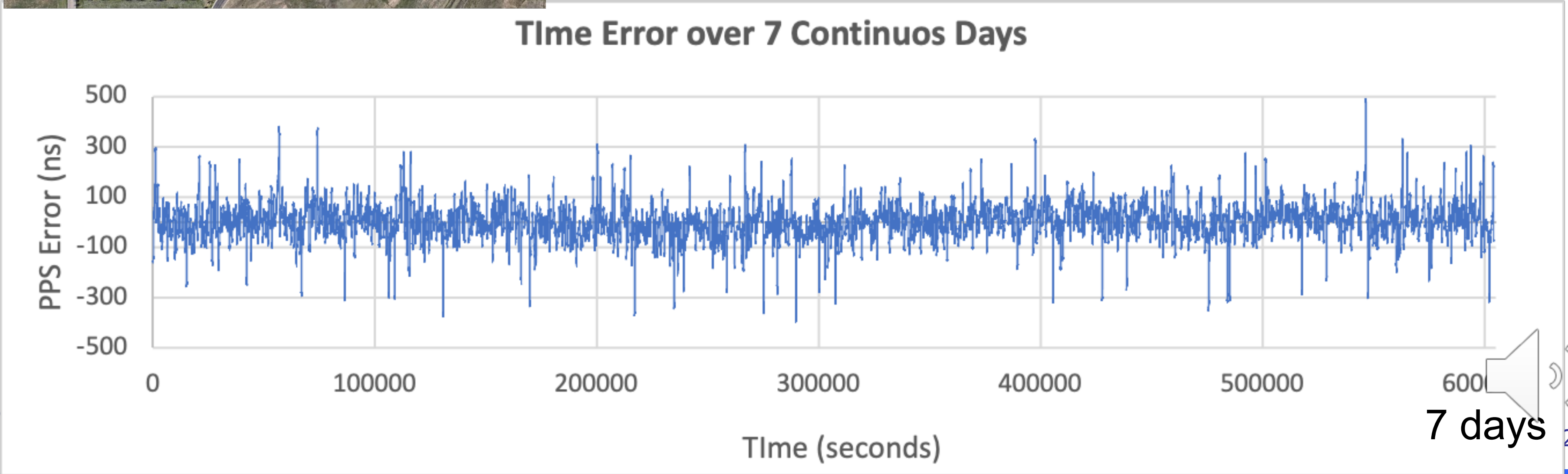
~100 ns peak error

Customer Building in Colorado-7 Day Test



EIA-GPS receiver on first floor building center of 2 story Building

Std 84 ns
Pk error 494 ns



7 days

Conclusion

- Extensive Internet Assisted GPS/GNSS systems with SDR in the cloud provides excellent and low cost, partly due to the elimination of PTP aware networks and roof top antennas, time for indoor devices and services. SDR provides an easy path to employ other GNSS systems.

Thankyou

Reference:

[1] An Analytical Method to Determine Squaring Loss and Weak ...
https://www.ion.org/publications/abstract.cfm?articleID=13046
Kurby, Christopher N., "**An Analytical Method to Determine Squaring Loss and Weak Signal Post Correlation SNR for a Broad Clas GNSS Signals,**" Proceedings of the 28th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS 15), Tampa, Florida, September 2015, pp. 2875-2886.