Backup Timing Source for Synchrophasor Using Chip-Scale Atomic Clock

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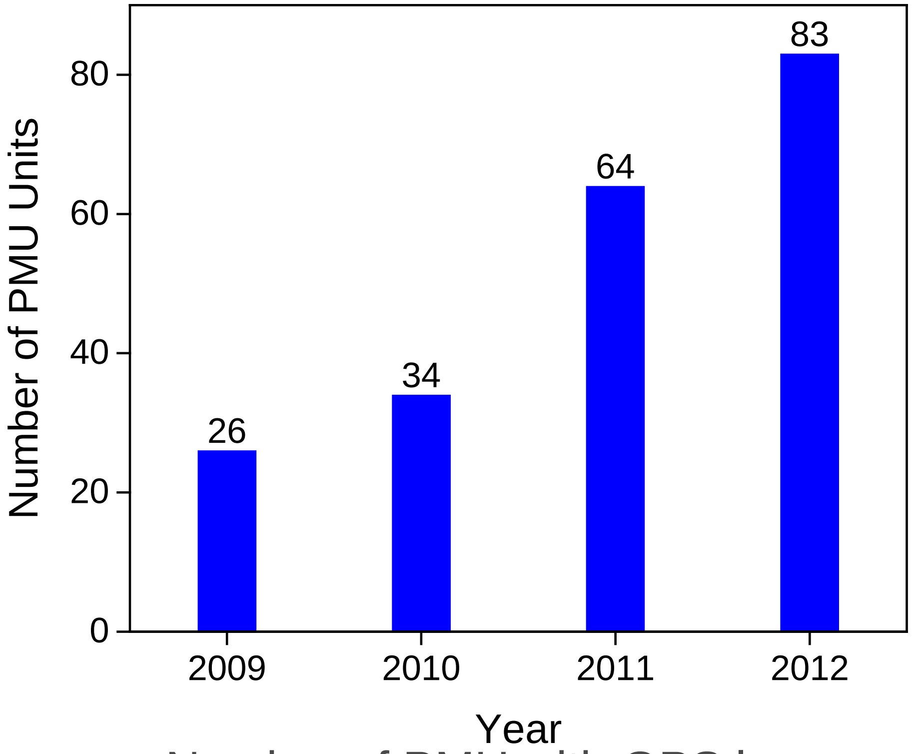
Motivation

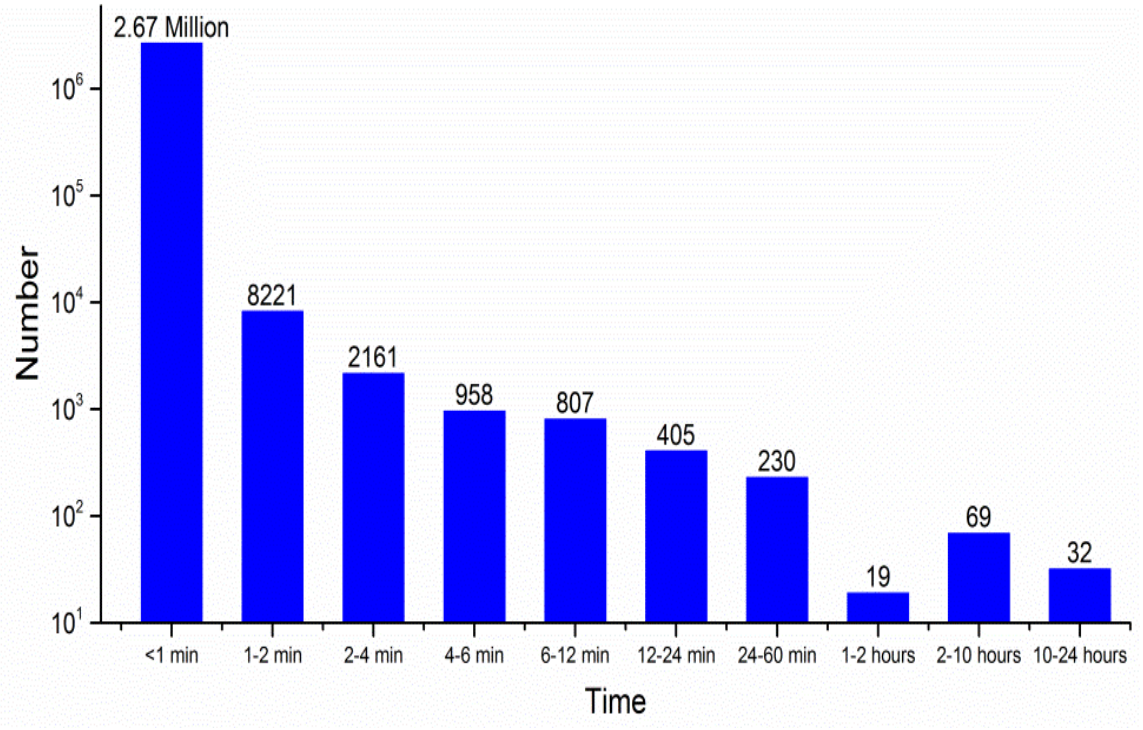
- Synchrophasors highly rely on timing source
  - Time stamp
  - Measurement accuracy
  - Data availability
- GPS Vulnerability
  - Atmospheric disturbance
  - Solar activity
  - Jamming & Spoofing
  - System failure

GPS Loss in PMU

- In a statistic of 4-year data, one PMU lost GPS signal **5 times per day**, and the duration is **6.7 seconds per loss**, in average.



Number of PMU with GPS loss

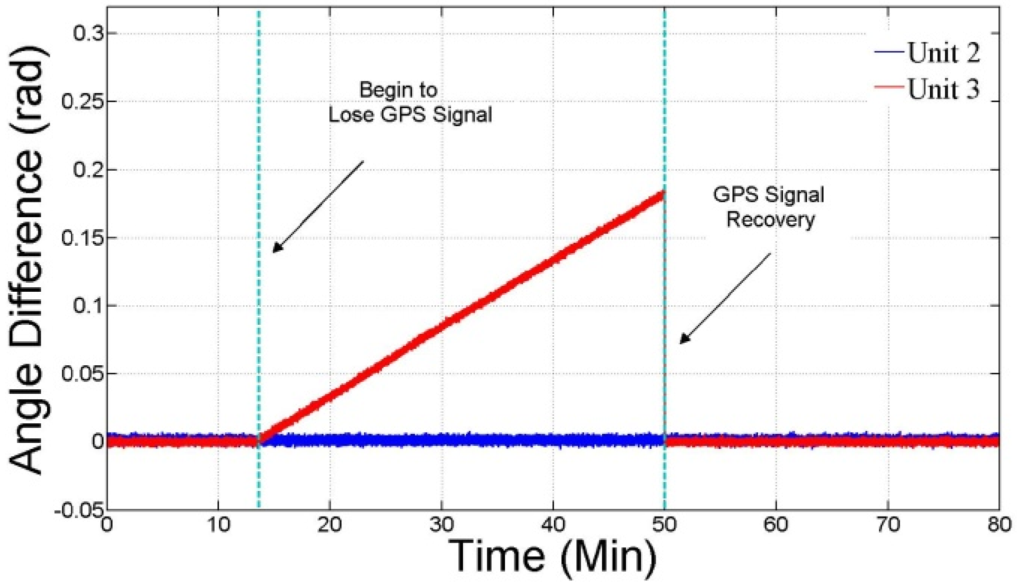


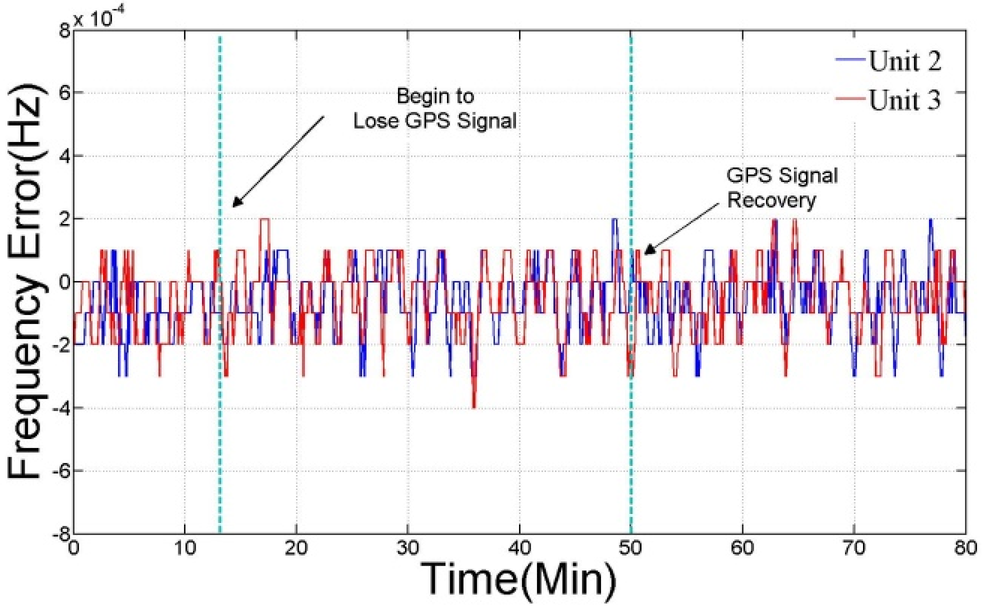
Count of GPS loss recovery time

D. Zhou, Z. Pan, Y. Liu, "Patterns of GPS timing signal loss of synchrophasor measurements"

Impact of GPS Loss

- Timing relies on the unprincipled oscillator during GPS loss
- Induce obvious phase angle error





W. Yao, L. I. U. Y, D. Zhou, Z. Pan, J. Zhao, M. Till*, et al.*, "Impact of GPS Signal Loss and Its Mitigation in Power System Synchronized Measurement Devices," *IEEE Trans. Smart Grid,* vol. PP, pp. 1-1, 2016.

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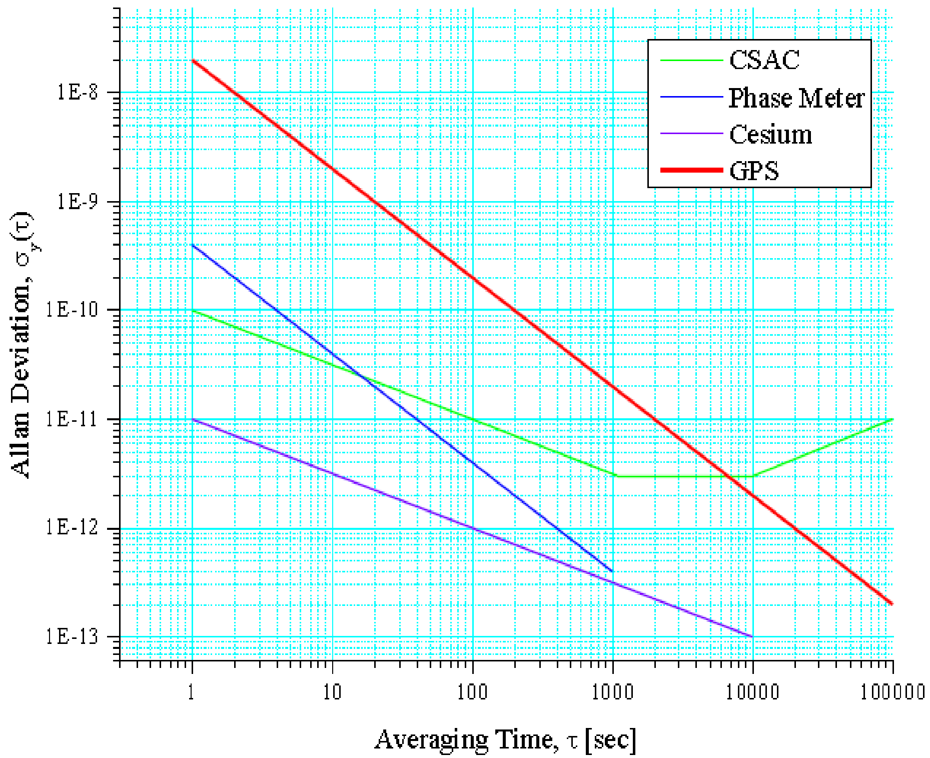
Chip-Scale Atomic Clock

- Chip-scale atomic clock (CSAC)
  - Independent timing source
  - More stable than GPS within 5,000 sec
  - Small size and power consumption



Source: www.microsemi.com

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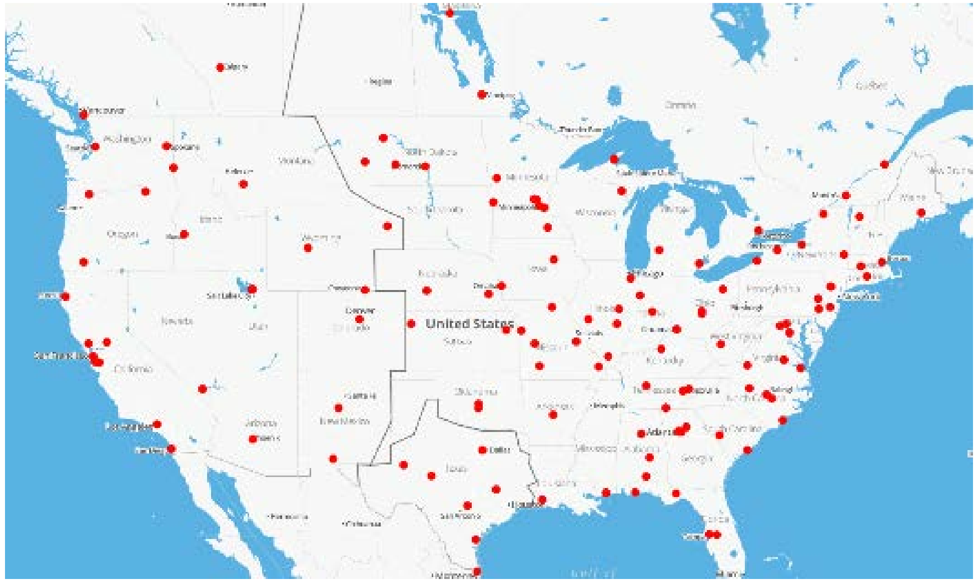
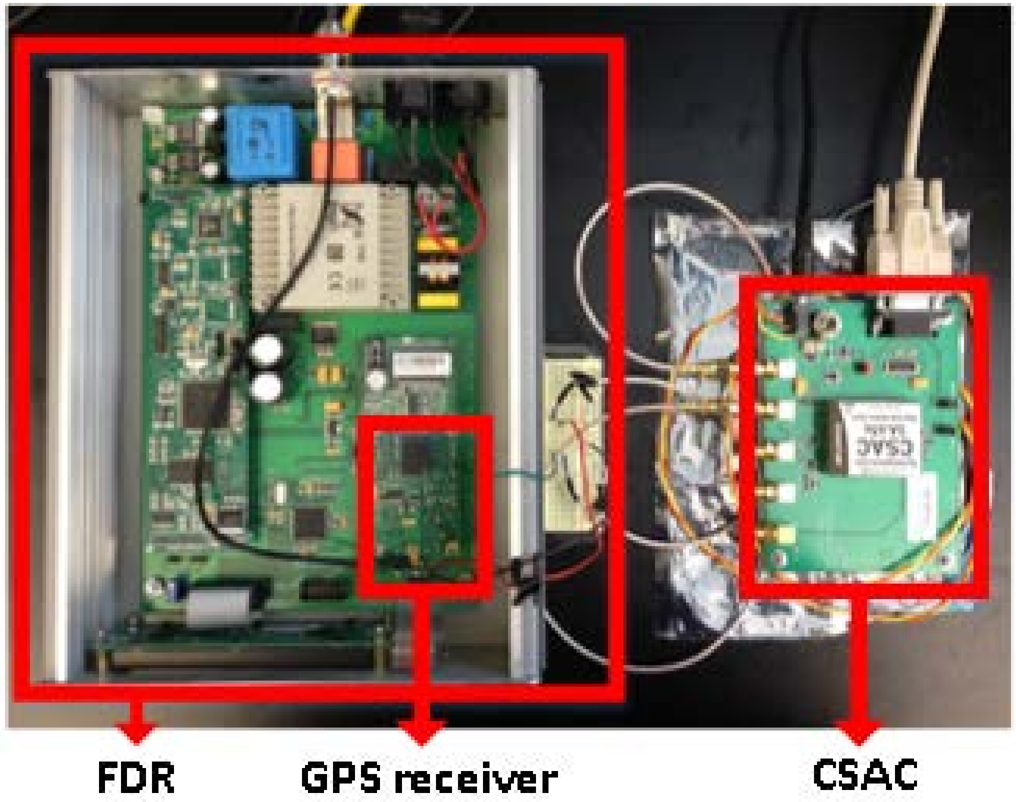
Using CSAC for FDR as Backup Timing Source

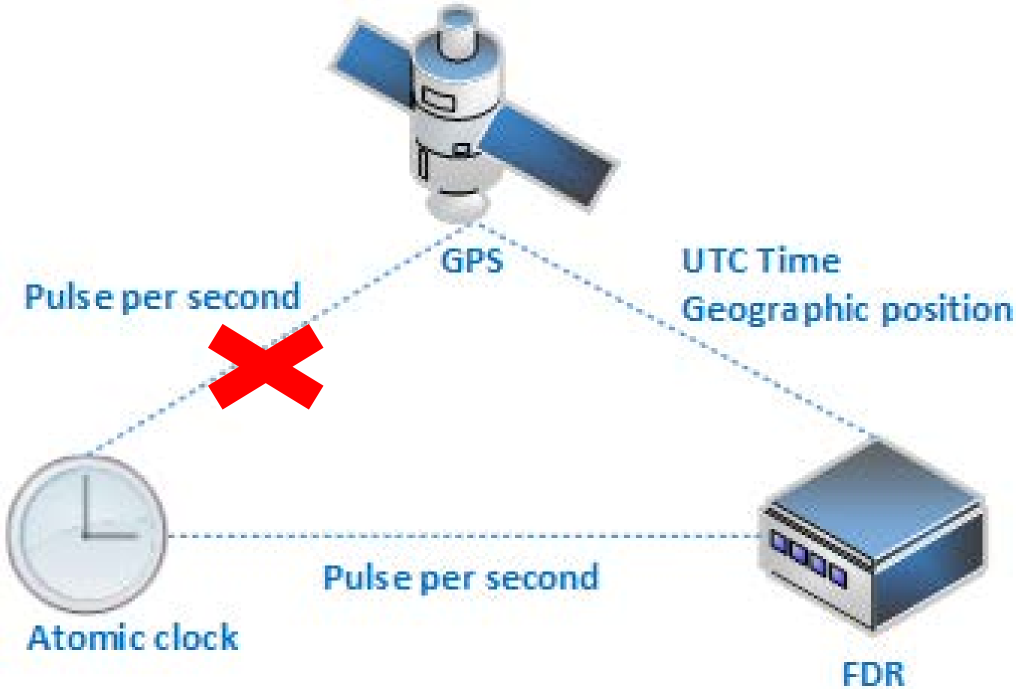
- Frequency Disturbance Recorder (FDR)
- A distribution level single-phase synchrophasor
- Sensor for Frequency Network (FNET/GridEye)



Testing System

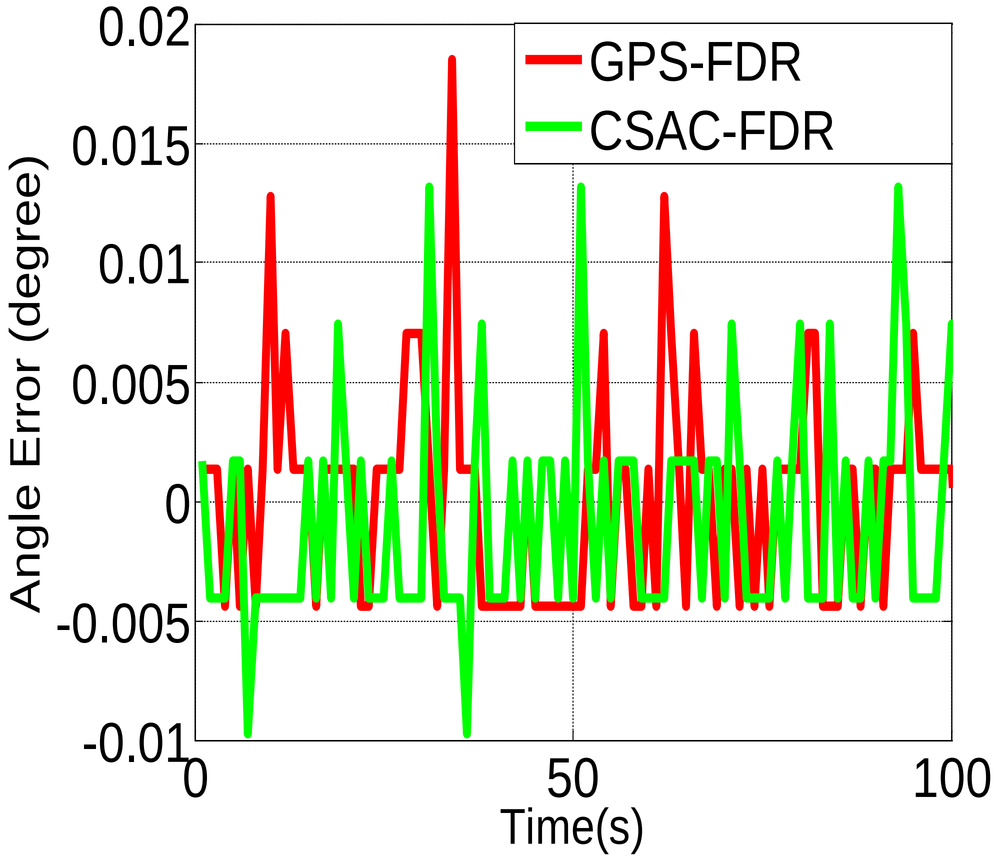
- CSAC can work under the GPS discipline (accurate stand-by status)
- In this test, the CSAC works with no GPS



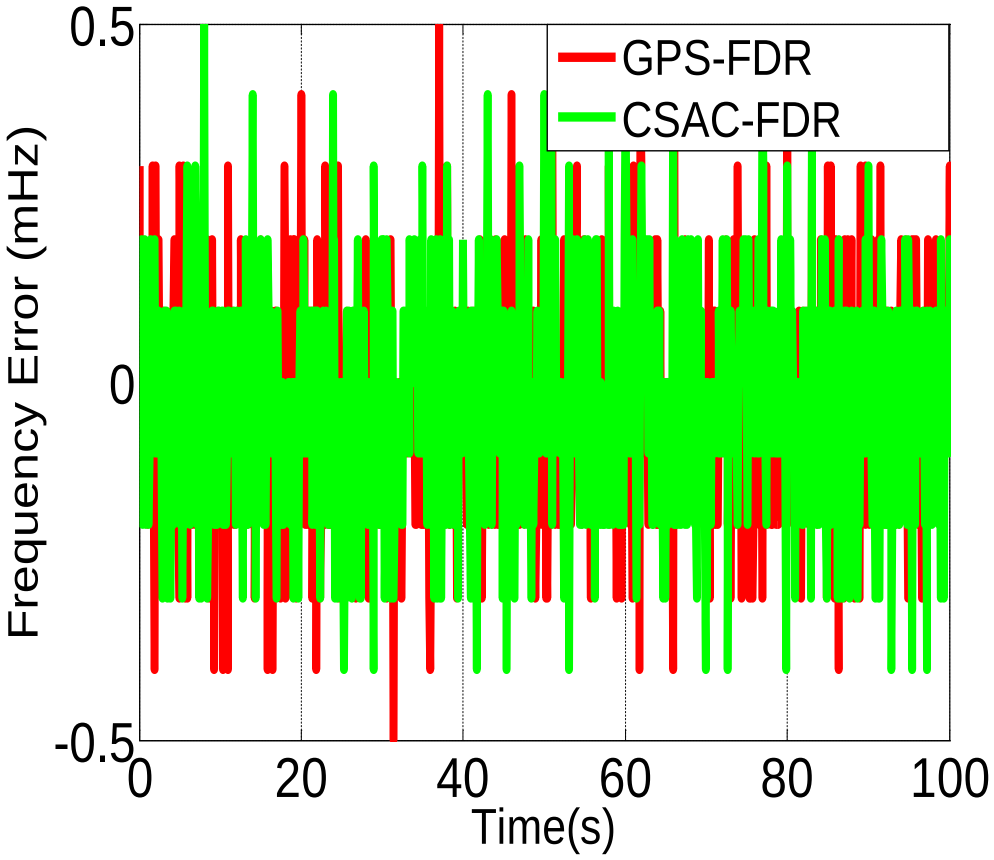


Comparison: Phase Angle & Frequency (short term)

- Phase Angle
  - Error < ±0.02°



- Frequency
  - Error < ± 0.5 mHz



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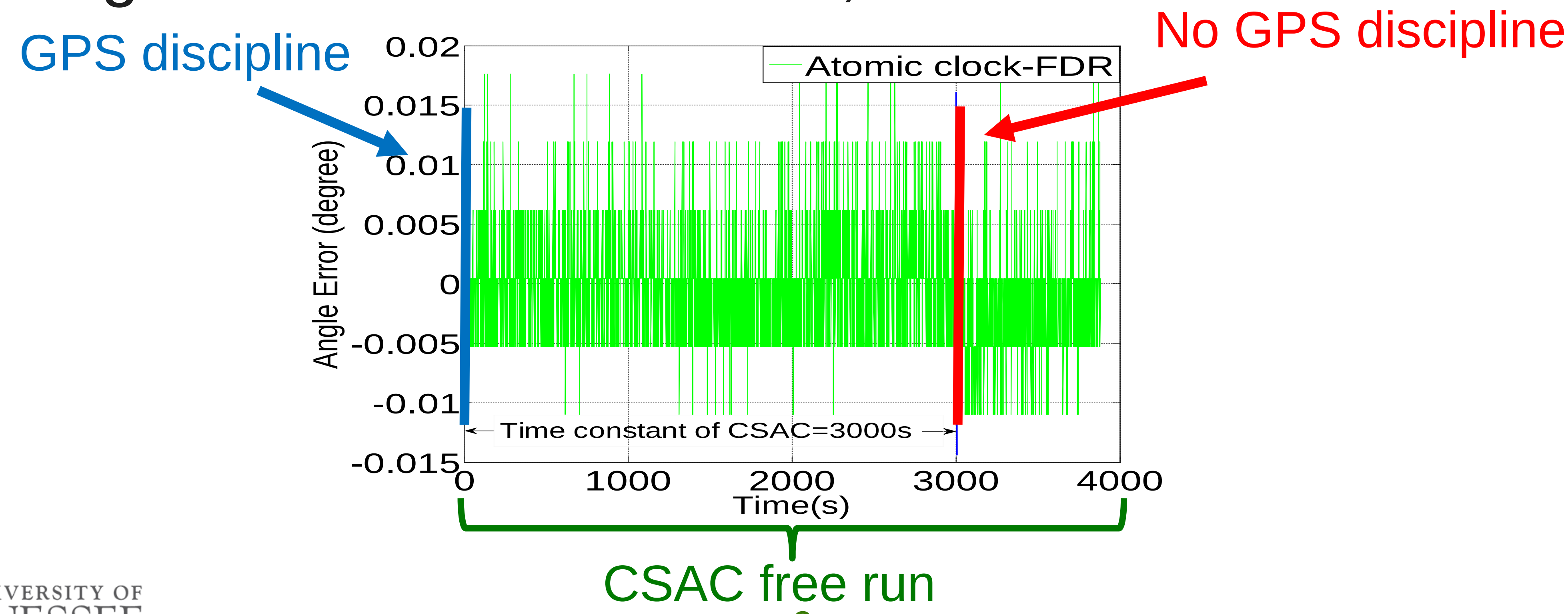
Testing: Mid-term

- CSAC is disciplined by GPS every 3,000 sec
- When there is no GPS, FDR using CSAC show small drift in angle measurement after 3,000 sec



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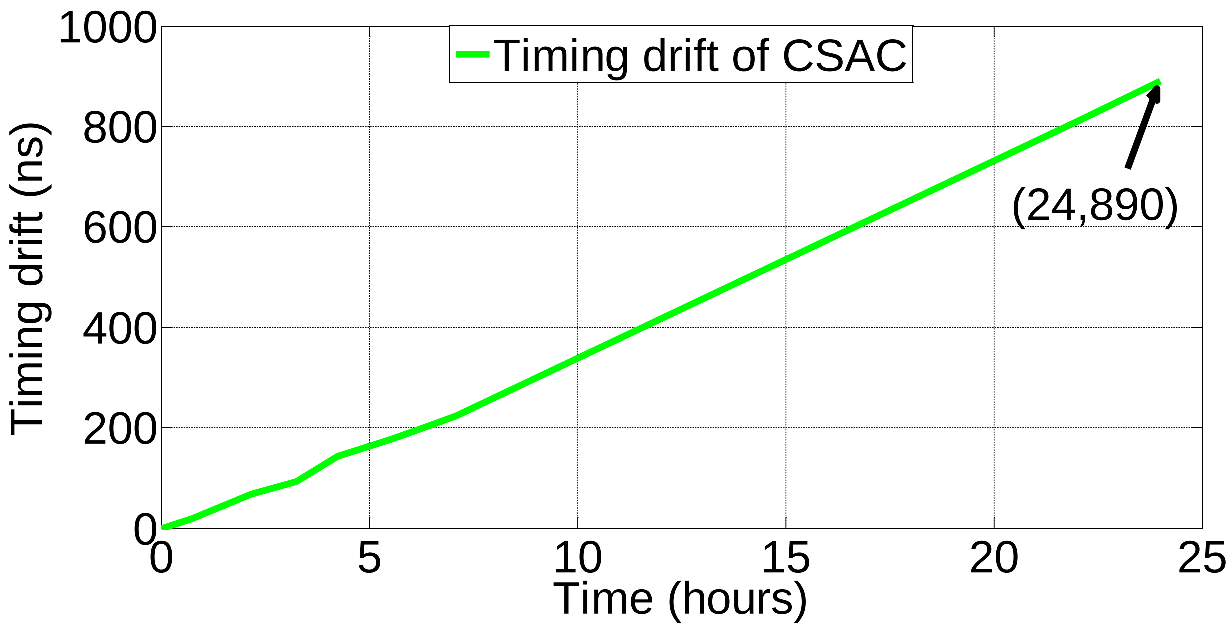
PPS Accuracy (Long term)

- Compare PPS between CSAC & GPS
- Drifting 890 ns in 24 hours
- Equivalent to 0.0192° for 60 Hz power grid



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Conclusion

- Synchrophasor shows comparable accuracy with CSAC and GPS in short term
- Good for at least one day (cover most GPS loss/malfunction durations)
- A good backup timing source for critical synchrophasor applications

Questions?

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