Synchrophasors Using eLoran Timing Source

Erik Johannessen[1], Andrei Grebnev[1], Stephen Bartlett[1],
Lingwei Zhan[2], Jiecheng Zhao[3], Yilu Liu[2, 3]

(1. UrsaNav Inc., 2. Oak Ridge National Laboratory, 3. the University of Tennessee, Knoxville)

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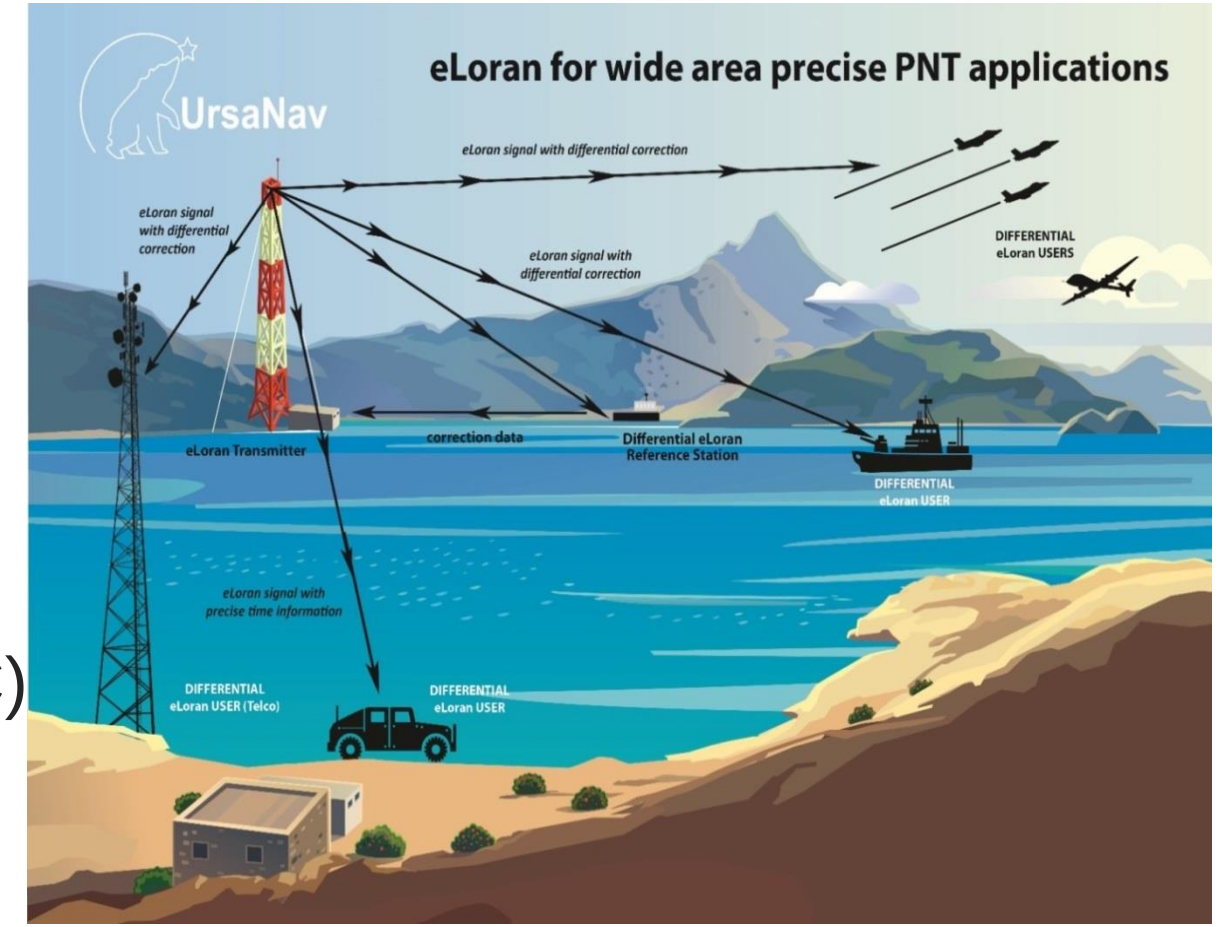
NASPI Group Meeting

Motivation

- Synchrophasors highly rely on timing source
  - Accuracy
  - Reliability
- GPS Vulnerability
  - Antenna needs clear view of the sky
  - Radio frequency interference
  - Jamming & Spoofing
  - System failure

e-Loran Timing System

- Structure
  - Modern Control Center
  - Modern Transmitting Sites
  - Differential Reference Stations
  - ASF Maps
- Performance
  - Accurate (synchronized to UTC)
  - Precise with differential corrections(± 100 ns)
  - Robust to failures of GPS



e-Loran Timing System

- Independent of GNSS
- Traceability to UTC < 50 ns
- Ground propagation
- All-in-view signal
- Loran Data Channel (LDC)
- Very high power
- Hard to spoof or jam

UN-152A e-Loran timing receiver

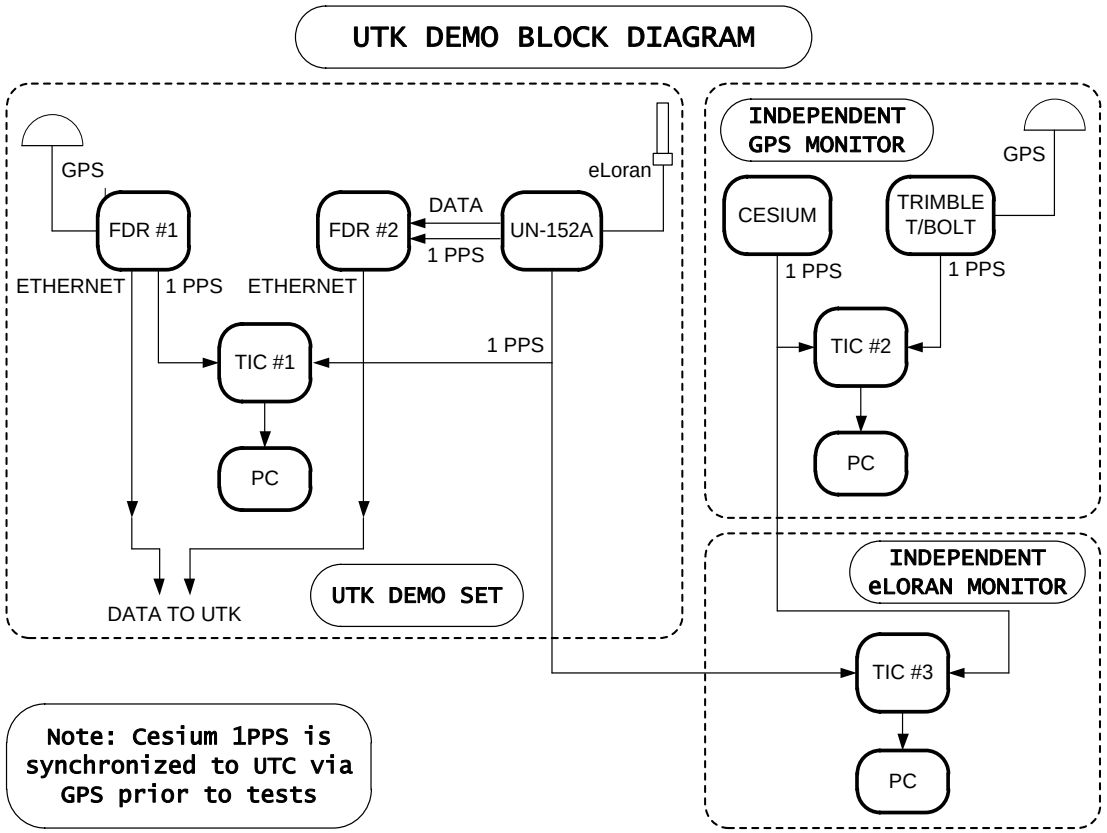
Using eLoran for FDR

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

Testing System

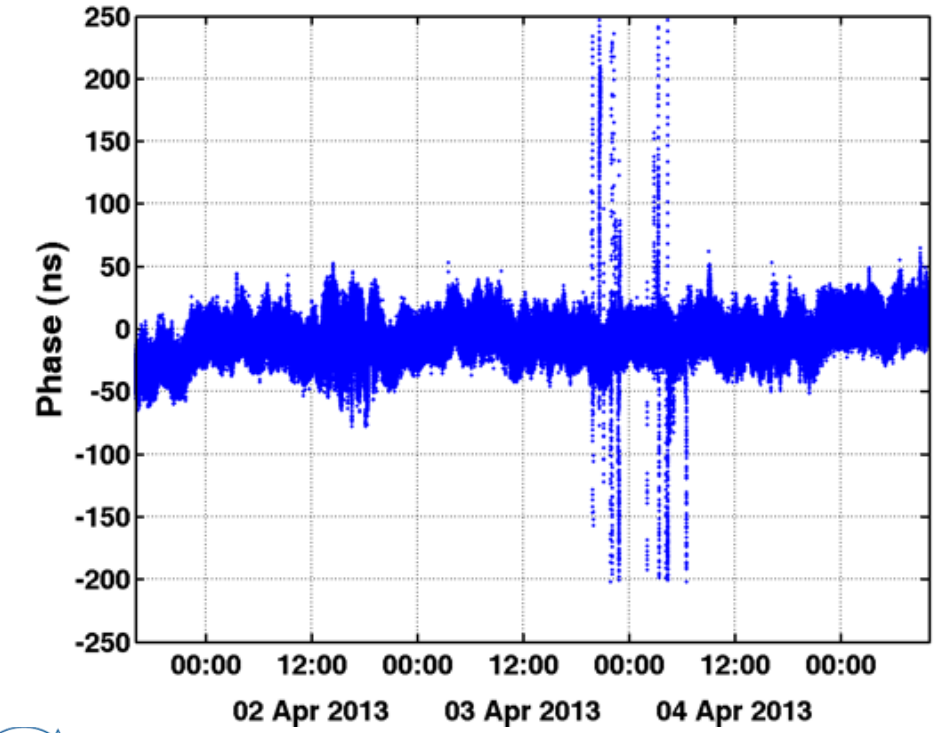
- Compare eLoran and GPS
- Use a Cesium atomic clock as time reference
  - Evaluate the PPS accuracy of GPS and eLoran
  - Stability: 1×10^{-7} ppm
- Use FDR for measurement testing
  - Phase angle accuracy: ± 0.029°
  - Frequency accuracy: ± 0.5 mHz

Testing System

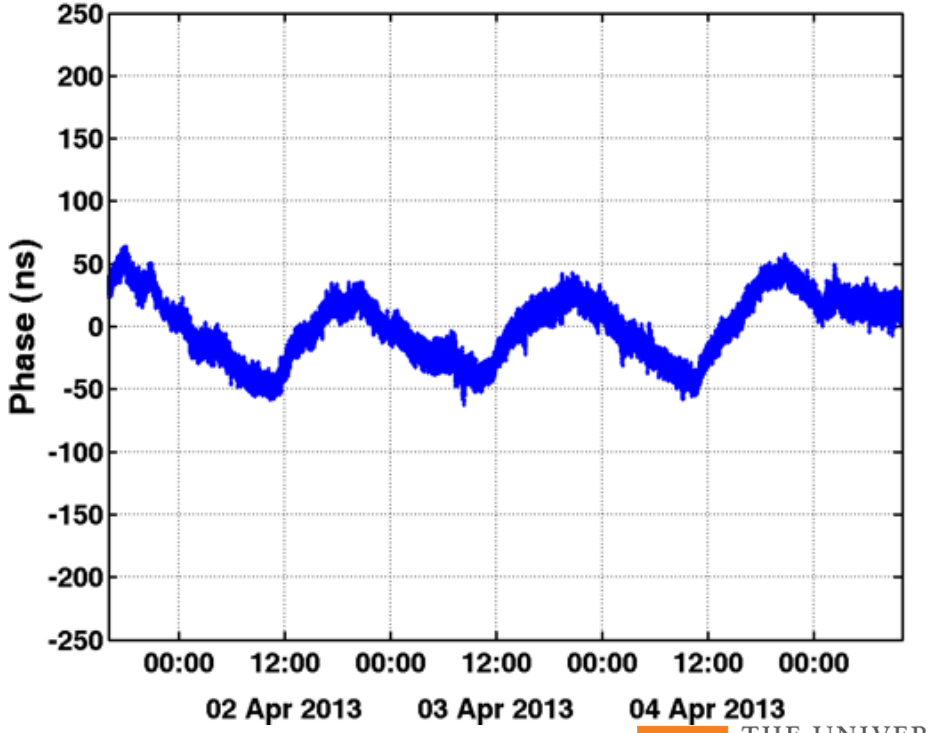


PPS Accuracy

- GPS (M12+)
  - Short term error < ± 30 ns
  - Long term error < ± 75 ns
  - Lost signal several times



- eLoran (UN 152A)
  - Short term error < ± 10 ns
  - Long term error < ± 75 ns
  - Not signal loss



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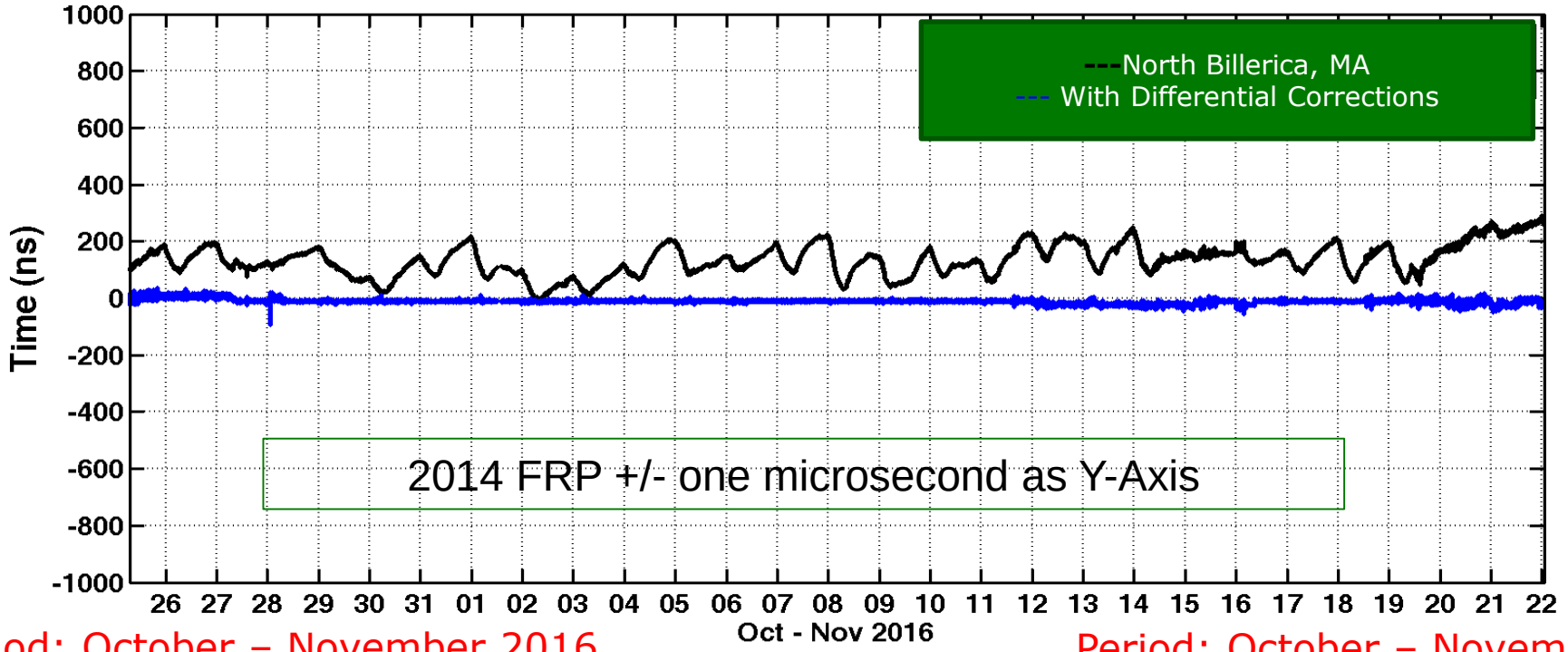
PPS Accuracy



Period: October – November 2016
Distance to XMTR: 310 miles
Without Differential corrections
Mean: 134.1
Std : 54.6
Max : 292.0
Min : -12.0

Period: October – November 2016
Distance to XMTR: 310 miles
With Differential corrections
Mean: -10.5
Std : 8.1
Max : 38.0
Min : -95.0

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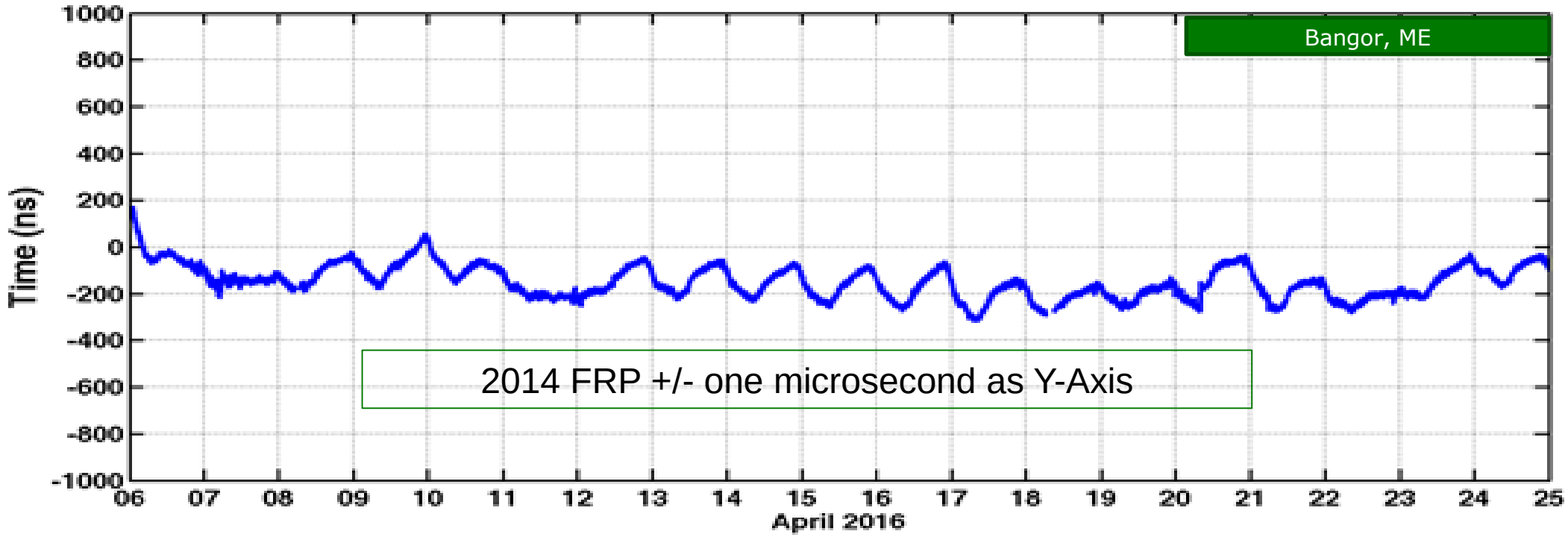
PPS Accuracy



Period: April 2016

Distance to XMTR: 500 miles

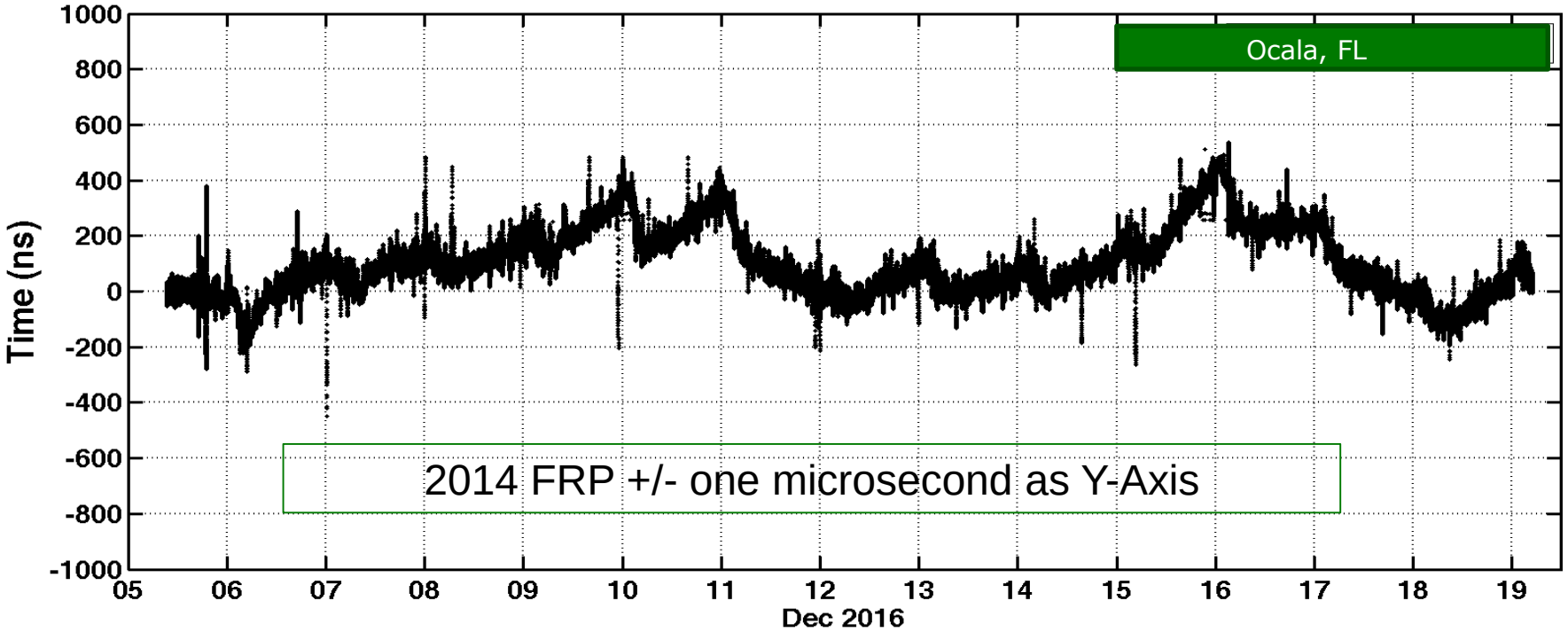
Mean: -149.1 ns

STD: 69.7 ns

Max: 171.0 ns

Min: -318.0 ns

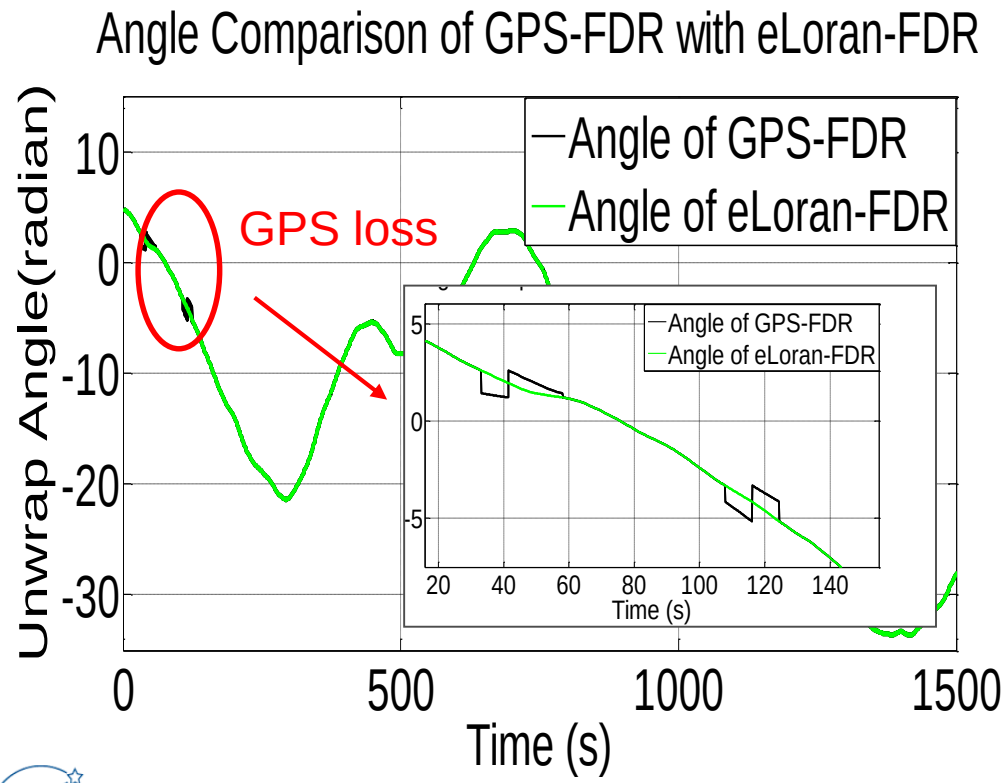
PPS Accuracy

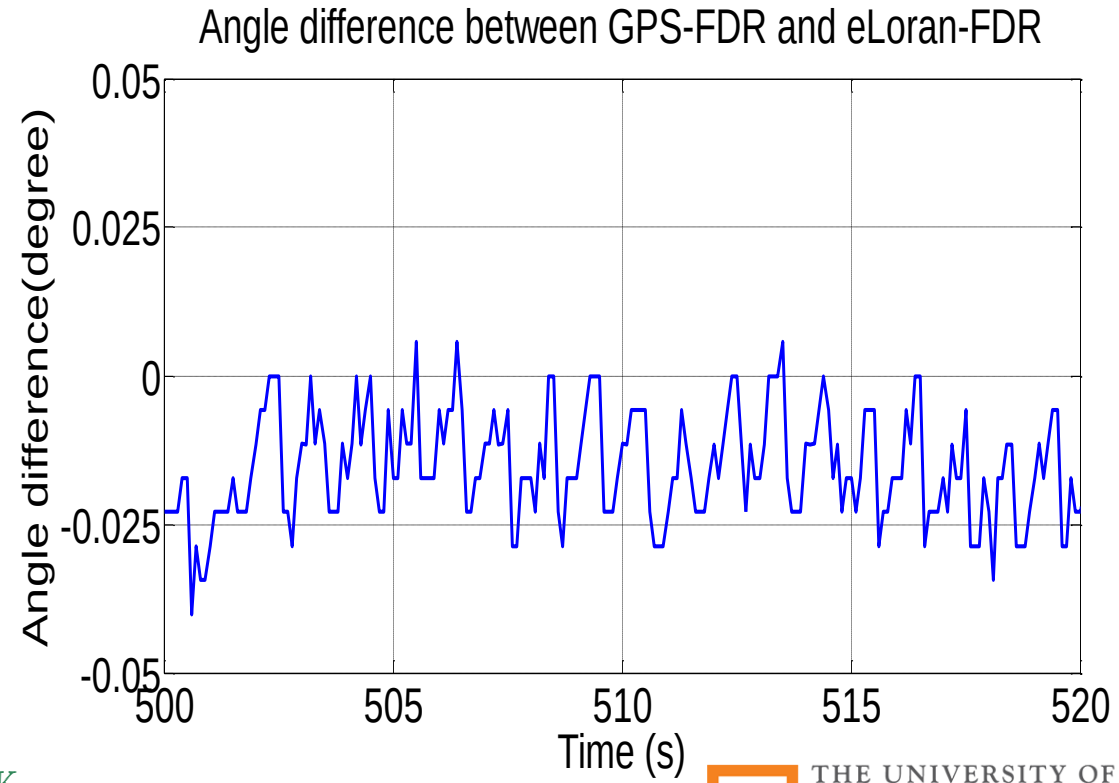


Period: December 2016
Distance to XMTR: 790 miles
Mean: 93.0
Std : 114.7
Max : 536.0
Min : -448.0

Comparison: Angle Measurement

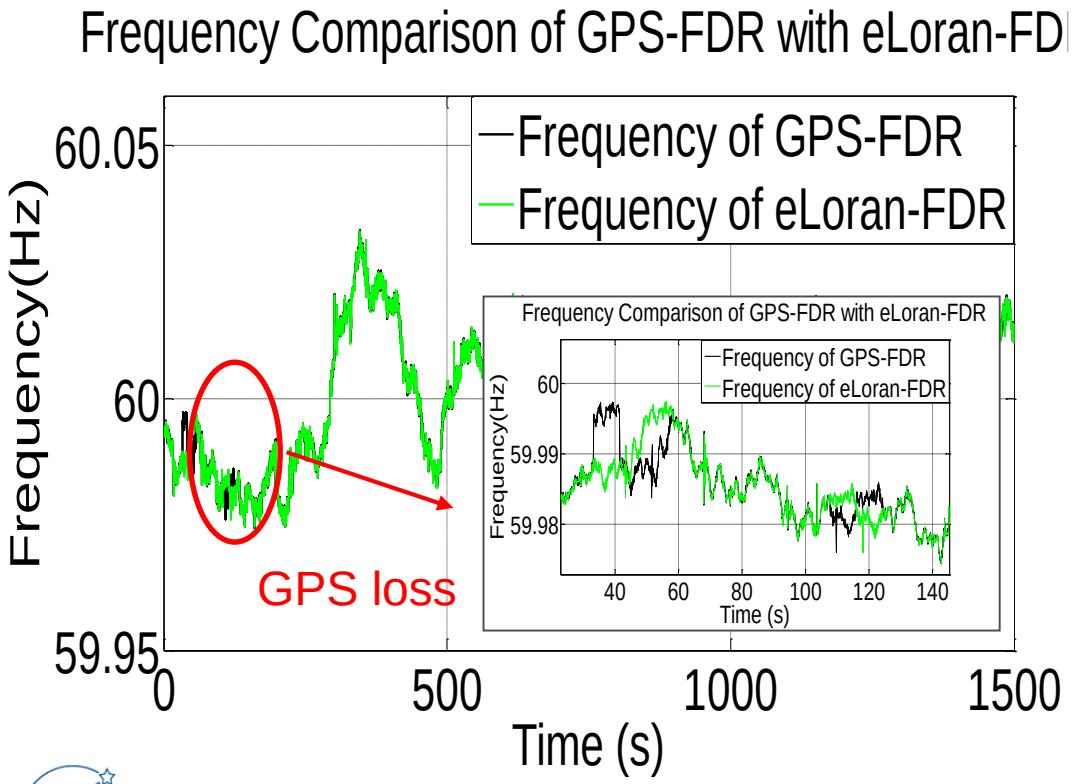
- Angle measurements agree with each other
- Difference < 0.046° (0.08% TVE)

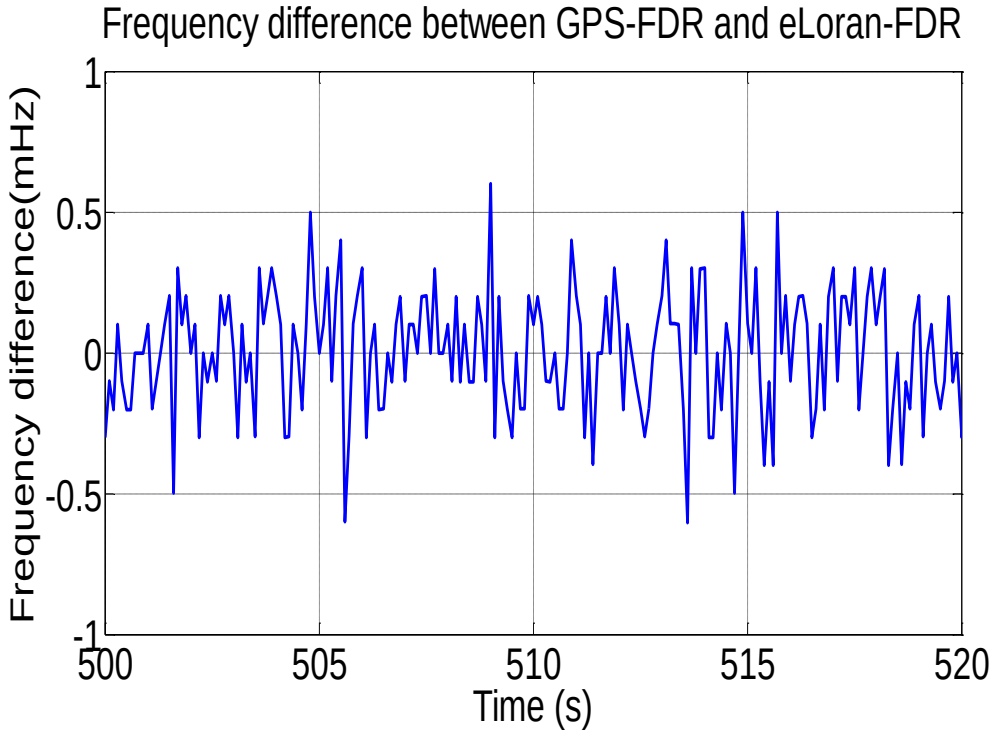




Comparison: Frequency Measurement

- Frequency measurements agree with each other
- Difference < ±0.5 mHz





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Summary of Result

- PPS timing error of both GPS and eLoran with differential corrections is well below 100 ns
- Angle difference between GPS-FDR & eLoran FDR
  - < 0.046° (0.08% TVE), within FDR's measurement accuracy
- Frequency difference between GPS-FDR & eLoran FDR
  - < ± 0.5 mHz, within FDR's measurement accuracy
- Timing availability in 3 days
  - GPS-FDR: lost 22 times (totally 63 min)
  - eLoran-FDR: no timing signal loss
  - eLoran PPS long term stability is good even at ~800 miles

Conclusion

- eLoran provides comparable PPS for synchrophasors
- Frequency and angle accuracy are comparable by using GPS and eLoran
- eLoran provides good signal availability and stability

Questions?