



ANNUAL INDUSTRY WORKSHOP
NOVEMBER 12-13, 2014

Robust GPS-Based Timing for Phasor Measurement Units

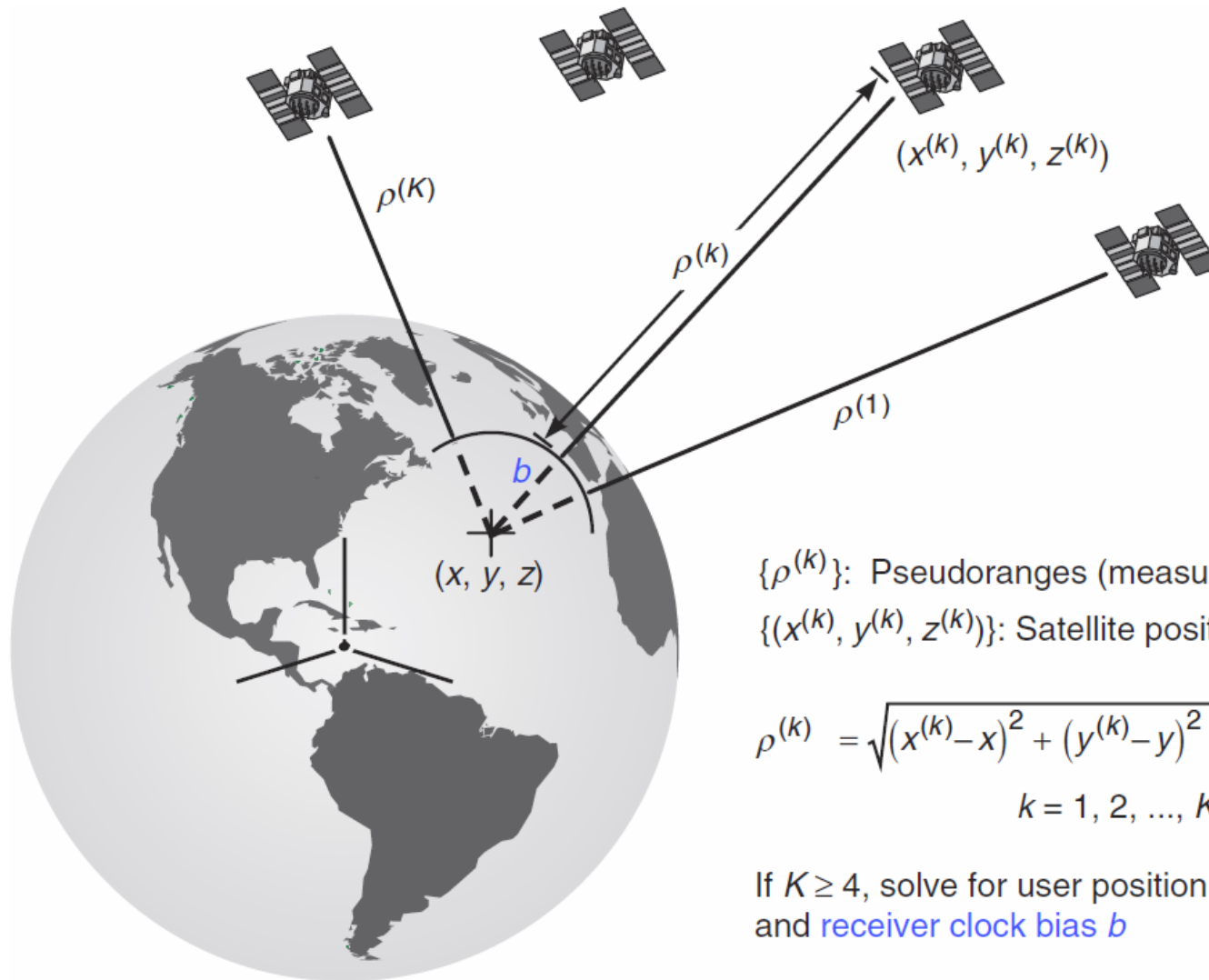
A Position-Information-Aided Vector Tracking Approach

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GPS Basics



$\{\rho^{(k)}\}$: Pseudoranges (measurements)

$\{(x^{(k)}, y^{(k)}, z^{(k)})\}$: Satellite positions (known)

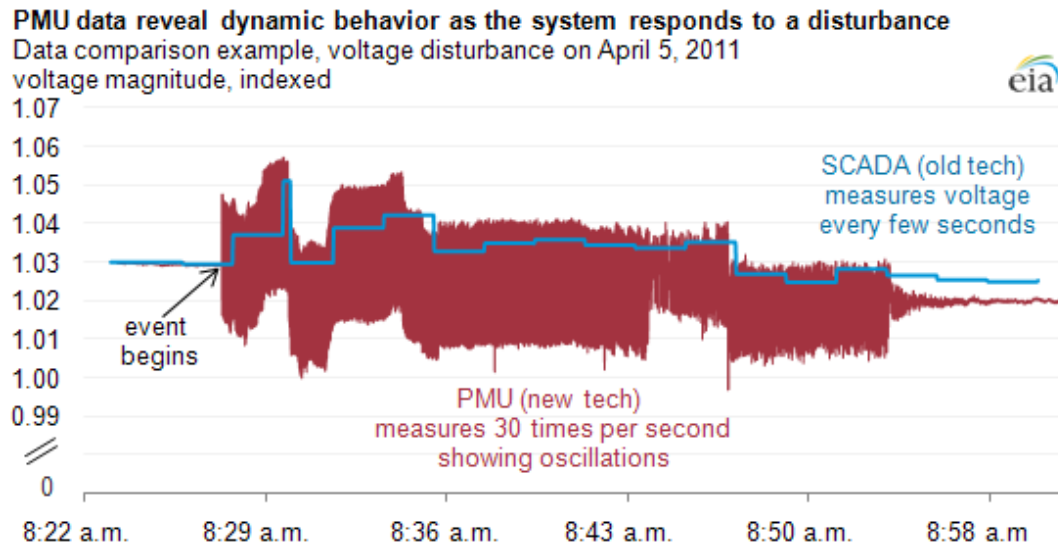
$$\rho^{(k)} = \sqrt{(x^{(k)} - x)^2 + (y^{(k)} - y)^2 + (z^{(k)} - z)^2} - b$$

$$k = 1, 2, \dots, K$$

If $K \geq 4$, solve for user position (x, y, z) ,
and receiver clock bias b

Phasor Measurement Units (PMU)

- Measures electrical waves to improve stability in power grids.
- Observation frequency:
 - SCADA: 1 sample every 4 seconds.
 - PMU: 30-60 samples/sec.
- Measurements time-stamped using GPS clock readings.
- Measurement information can be used to fine-tune the power grid to improve efficiency and detect instability and disturbances.



Motivation

- GPS robustness and reliability directly influences PMUs.
- GPS receivers are vulnerable to:
 - Frequency leakage from radio signals
 - Interfering electromagnetic fields
 - Accidental jamming
 - Spoofing attacks

Goals:

- Robustness against interference
- Spoofing detection
- Accurate timing solutions

NJ man faces nearly \$32K fine for disrupting Newark airport's satellite tracking system

NEWARK, N.J. — A New Jersey man faces tens of thousands of dollars in fines after regulators say he interfered with a satellite system at one of the nation's busiest airports while masking his whereabouts from his employer.

The Federal Communications Commission said Gary Bojczak admitted he installed a jamming device in his company-owned pickup to thwart his employer's GPS.

Bojczak surrendered the jamming device after his vehicle was stopped at Newark Liberty International Airport in August 2012.

The FCC said the jamming device interfered with a new system that enhanced navigation signals that used GPS data to aid aircraft approaching, departing and on the ground. The system was

http://www.nj.com/news/index.ssf/2013/08/man_fined_32000_for_blocking_newark_airport_tracking_system.html

Outline

- Position-Information-Aided Vector Tracking
 - Approach
 - Implementation
- Experimental Results
 - Hardware
 - Tracking results
- Conclusions

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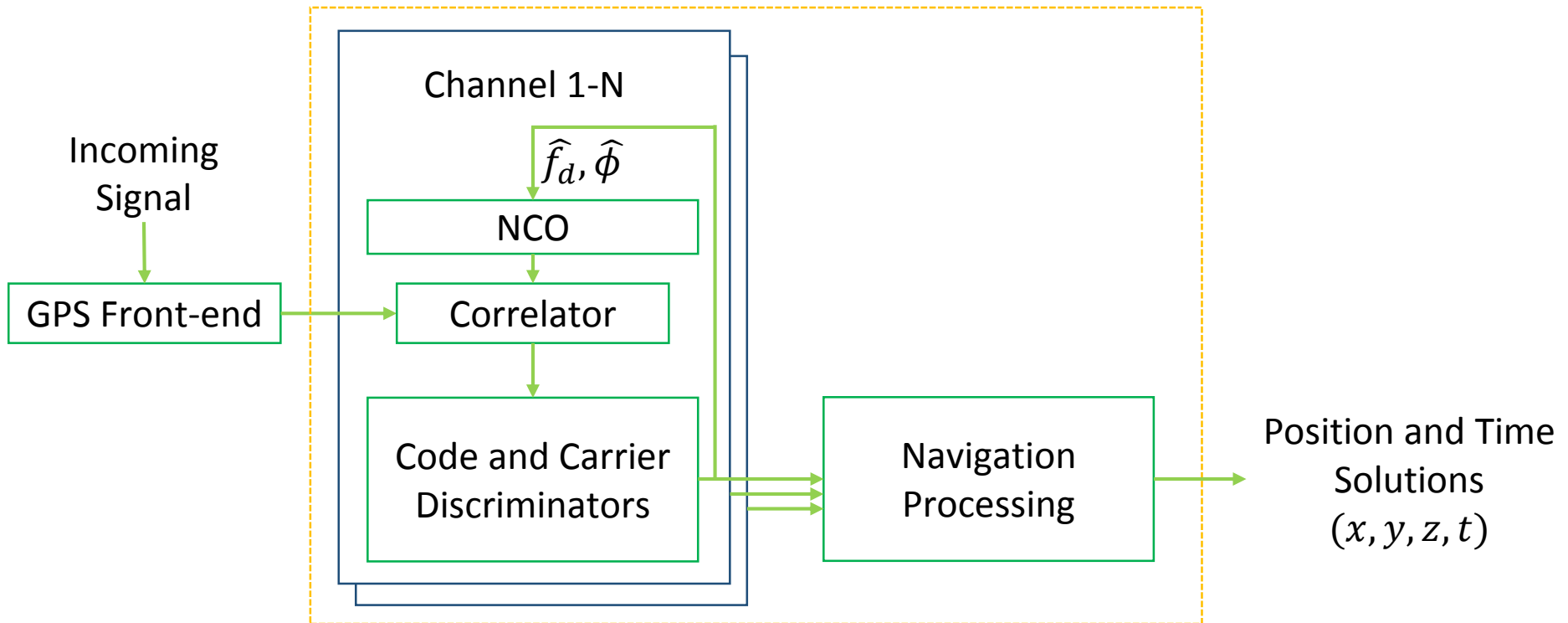
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Approach: Position-Information-Aided (P.I.A.) Vector Tracking

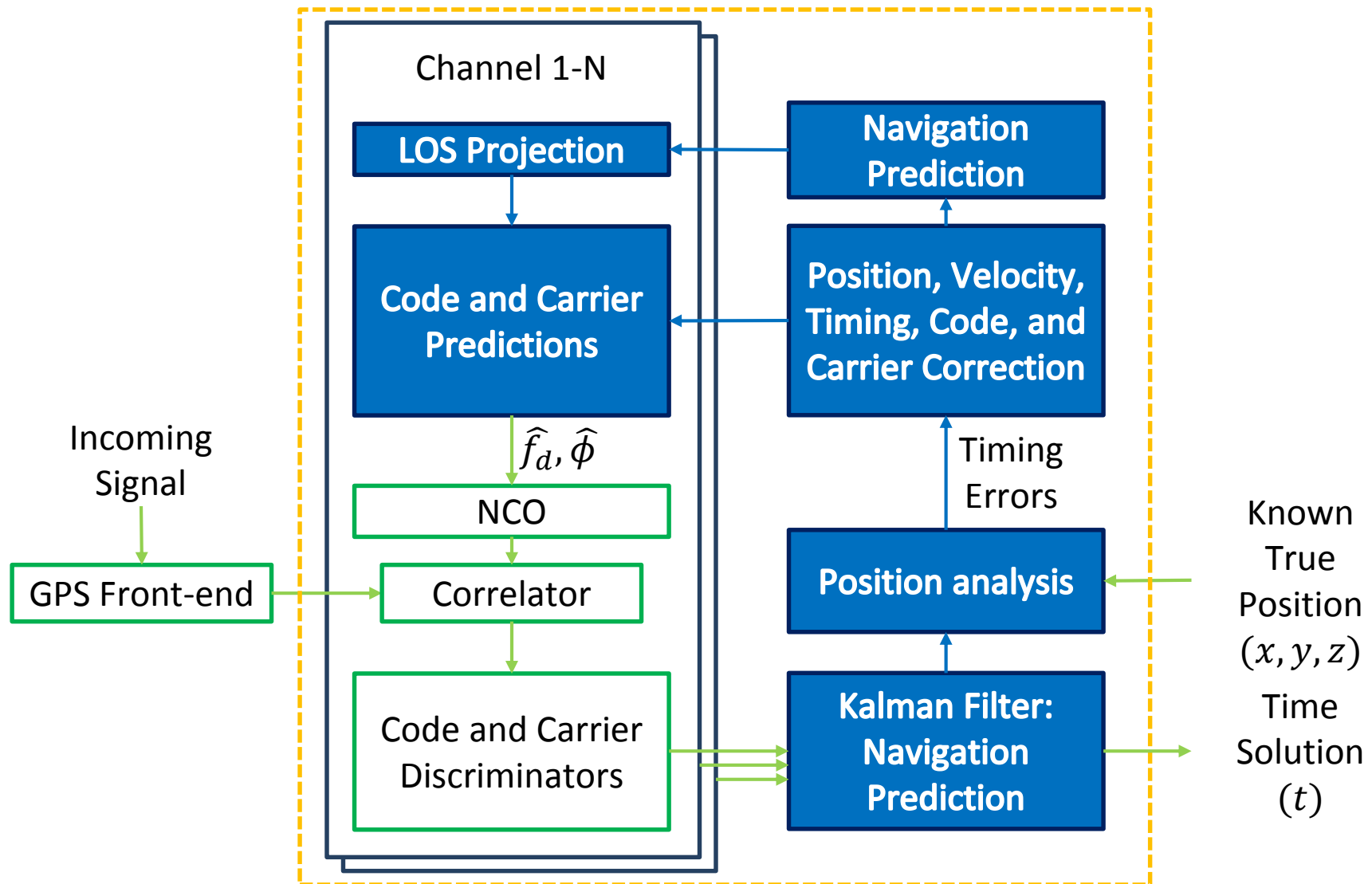
Approach:

- Vector tracking
- Reduces the search space
 - Aided by the true position
- Kalman filtering
 - Recursively predict and update the errors
- Narrowband loop filter

Scalar Tracking



Implementation: P.I.A. Vector Tracking



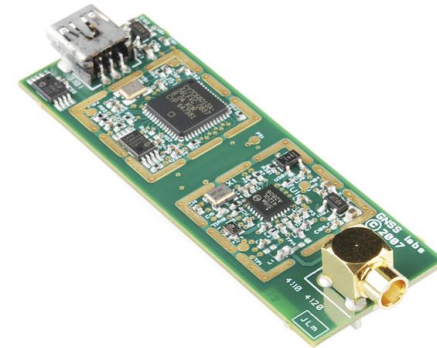
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GPS Front End

Receiver

- SiGe Sampler
 - 2 bit quantization
 - Bandwidth: 2.72MHz
 - Low-cost, off-the-shelf



Antenna

- Novatel Antenna
 - Fixed-reference antenna
 - Choke ring form



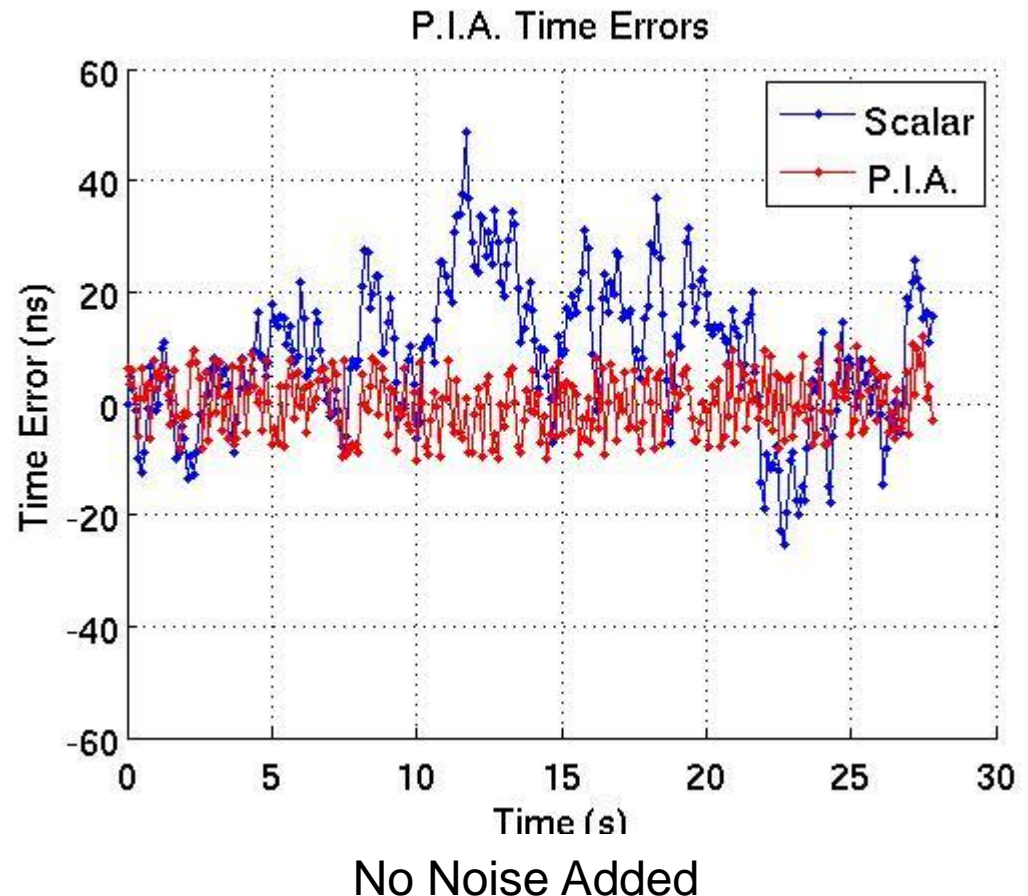
P.I.A. Vector Tracking Improves Accuracy

- Loop filter bandwidth of 5Hz for both scalar and P.I.A tracking loops.

- 9 satellites in view

Maximum errors:

- Traditional tracking
 - ~50ns
- Proposed vector tracking
 - ~15ns

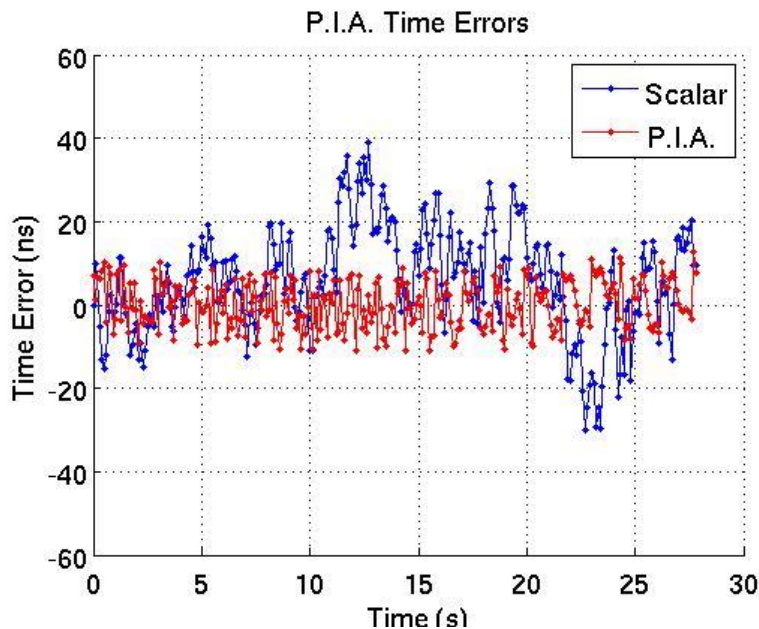


P.I.A. Tracking Increases Noise Tolerance

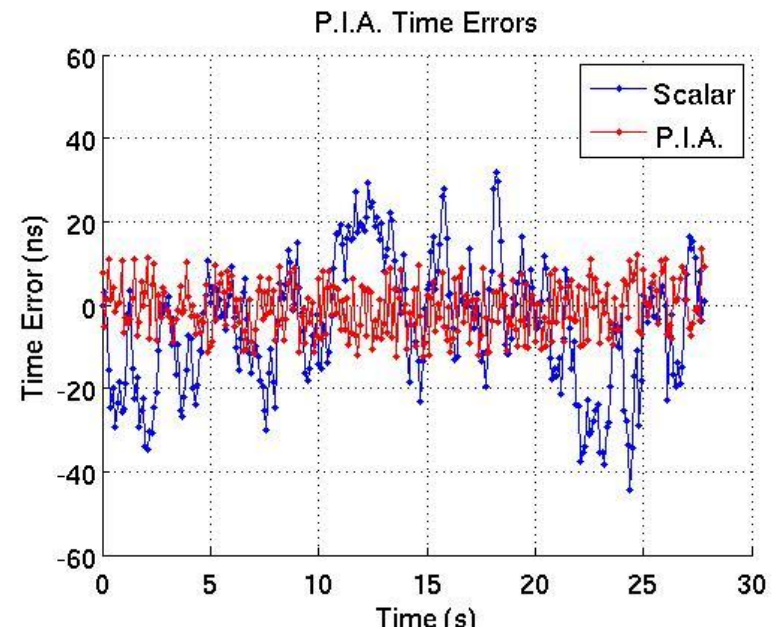
- Increased noise leads to loss of lock in scalar tracking.
- At 4 dB of additional noise, the scalar tracking was able to produce navigation bits for 4 satellites.

Noise Added	# of Satellites Tracked in Scalar
0 dB	9
1 dB	8
3 dB	5
4 dB	4

1 dB Noise Added



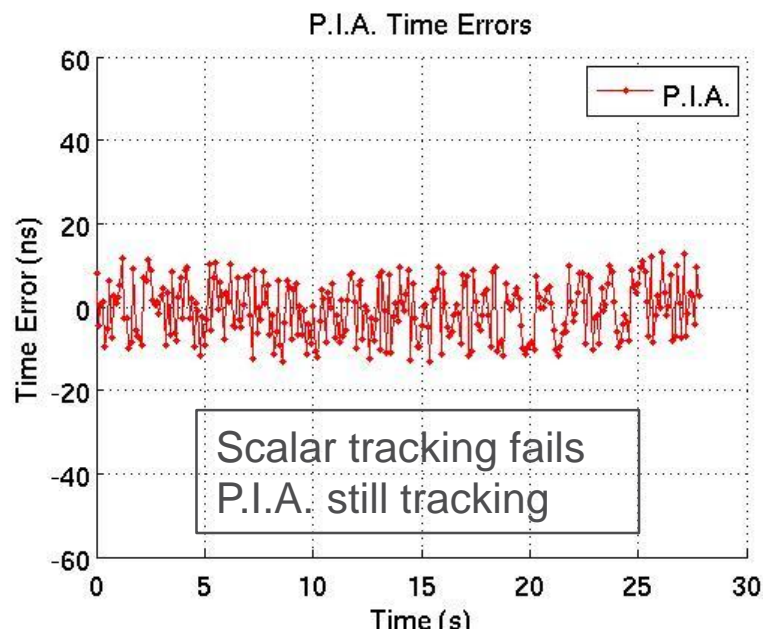
4 dB Noise Added



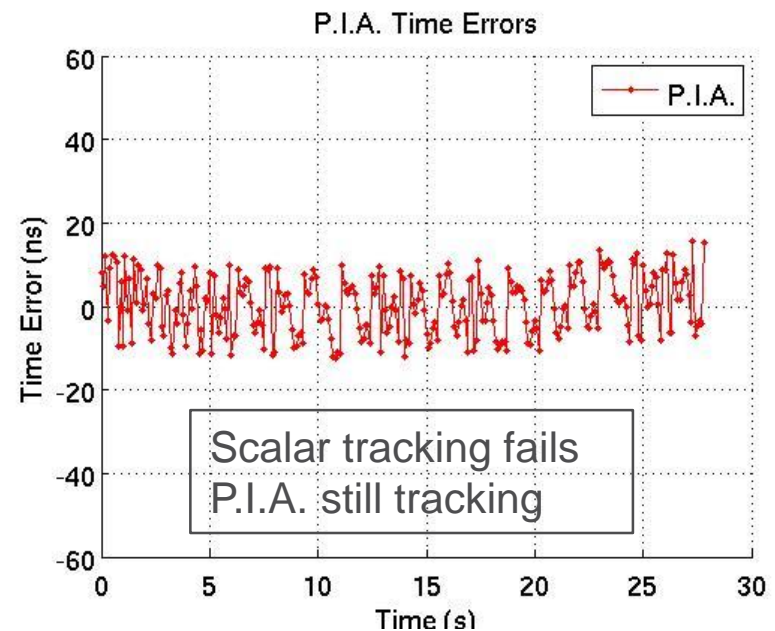
P.I.A. Tracking is Robust Against Jamming

- Scalar tracking fails at 5 dB of added noise.
- P.I.A. Vector Tracking continued to operate up until 9 dB of additional noise (5 dB more noise tolerance over scalar tracking)
- Reduces a jammer's effective radius.

5 dB Noise Added

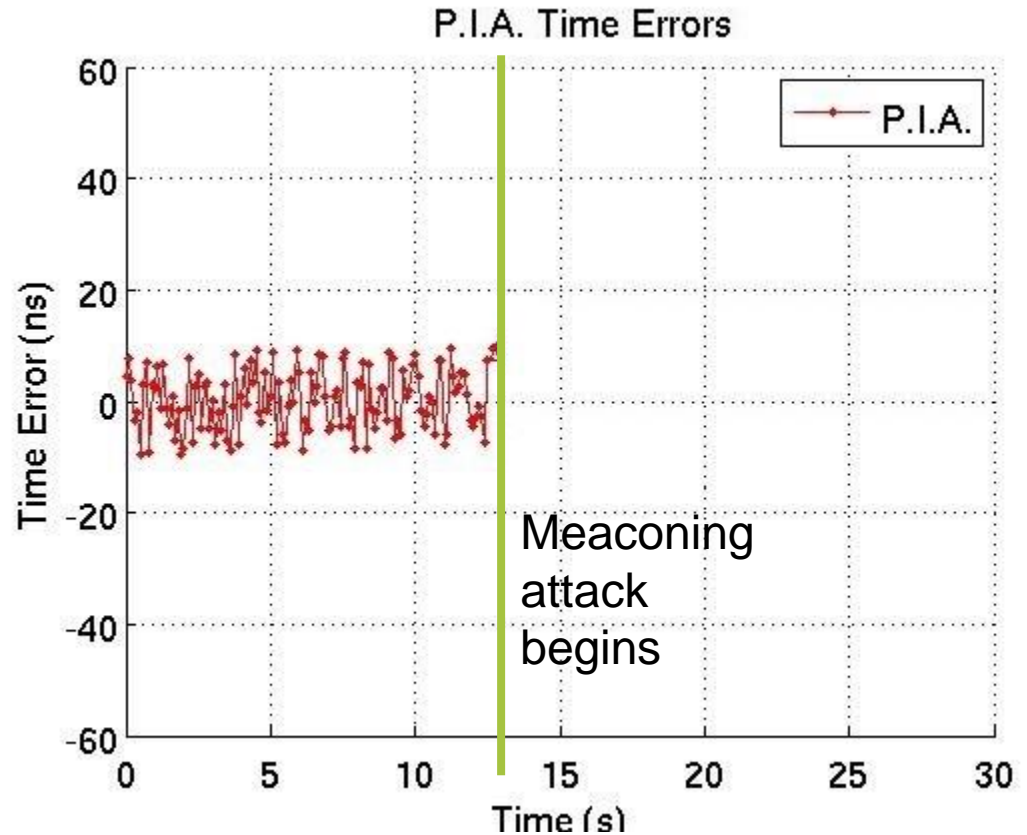


9 dB Noise Added



P.I.A. Tracking Detects Meaconing

- Meaconing: record and replay legitimate GPS signal.
- Meaconing attack simulated.
- P.I.A. Vector Tracking loop fails to converge in the event of a meaconing attack.
- 200 meter difference in known position and meaconing position.



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Conclusions

- Proposed the Position-Information-Aided Vector Tracking approach for GPS-based timing.
- Conducted experiments to evaluate the performance of the proposed approach.
- Validated:
 - Robust against jamming (5dB more noise tolerance compared with scalar tracking);
 - Successfully detects meaconing attacks;
 - Improves the accuracy of the timing solutions (15 ns vs 50 ns).