NIST-AMC Experiment to Transfer Time through a Public Network

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Outline

- Motivation
- Project plan
- Current results, October 2014
  - Transfer results using two transports
  - Diagnostic efforts to determine cause of asymmetry
- Concerns and next steps

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Motivation

- Need to back up critical infrastructure for time at microsecond (µs) or better
  - NTP over internet no better than ~ 1millisecond (ms)
- Research use of public telecom networks to transfer time
  - Optical fibers excellent for two-way time transfer
  - Public network fibers are unidirectional
- Need a method that is commercially viable
  - PTP is a new standard for time transfer
  - Format cannot improve accuracy - requires access to physical signal

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History of Project

- Centurylink provider agreed in principle to two-year experiment linking NIST Boulder and USNO AMC at Schriever AFB (Source of UTC from GPS)
- DHS issued RFI, December 2011
- One vendor, Symmetricom-Microsemi, gave a detailed plan
- Tri-lateral MOU written: DoC (NIST)-DHS-DoD (USNO)
  - Not yet signed
- Three-way Cooperative Research and Development Agreement (CRADA) NIST with Centurylink and Symmetricom-Microsemi signed in January 2013
- Currently working to extend past December 2014 to December 2015

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NIST-AMC Timing Experiment Microsemi PTP + CenturyLink Circuit

- Microsemi provides PTP timing signals over Gigabit Ethernet
- CenturyLink provides two different circuits to carry the timing signals
  - STS over SONET with varied bandwidths on an OC-192
  - OTN on an ODU-0, within an ODU-2 transport

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Time Transfer Experiment

- Two-way time transfer using neighboring unidirectional fibers
  - No time-awareness anywhere in network
  - No routers in path
  - No real traffic, though traffic noise can be added
- Measurements at NIST and AMC against UTC(NIST) and UTC(USNO)

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Results from PTP over SONET

- Large asymmetry of 40 µs between forward and reverse directions
  - Cause unknown
- Variations on order of 300 ns
  - Deterministic if nodes timed by Cs.
  - Random wander if nodes timed by GPS

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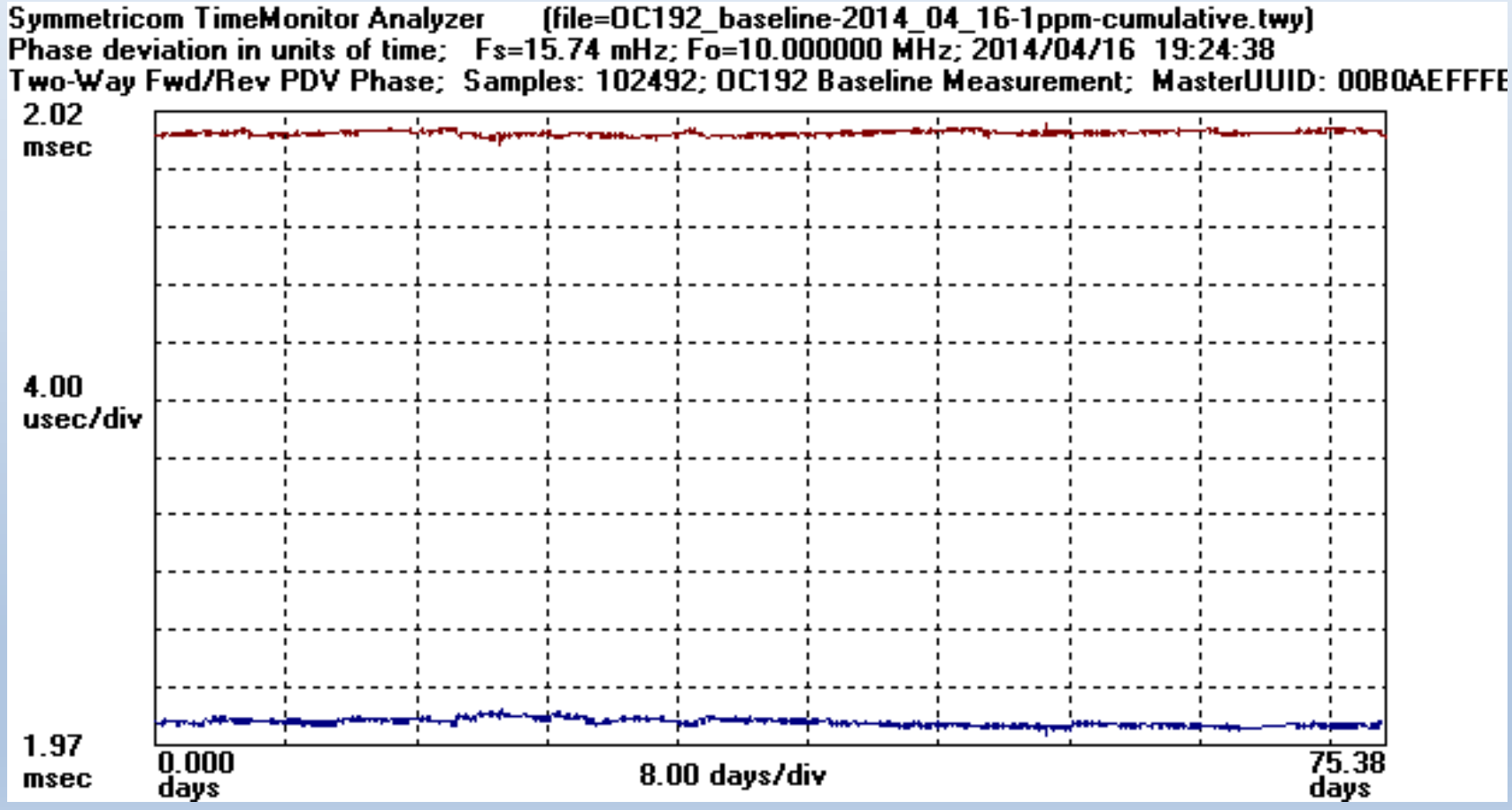
PTP over SONET

~2 ms total delay, 40 µs asymmetry

OC192 forward (blue) and reverse (red) packet delay



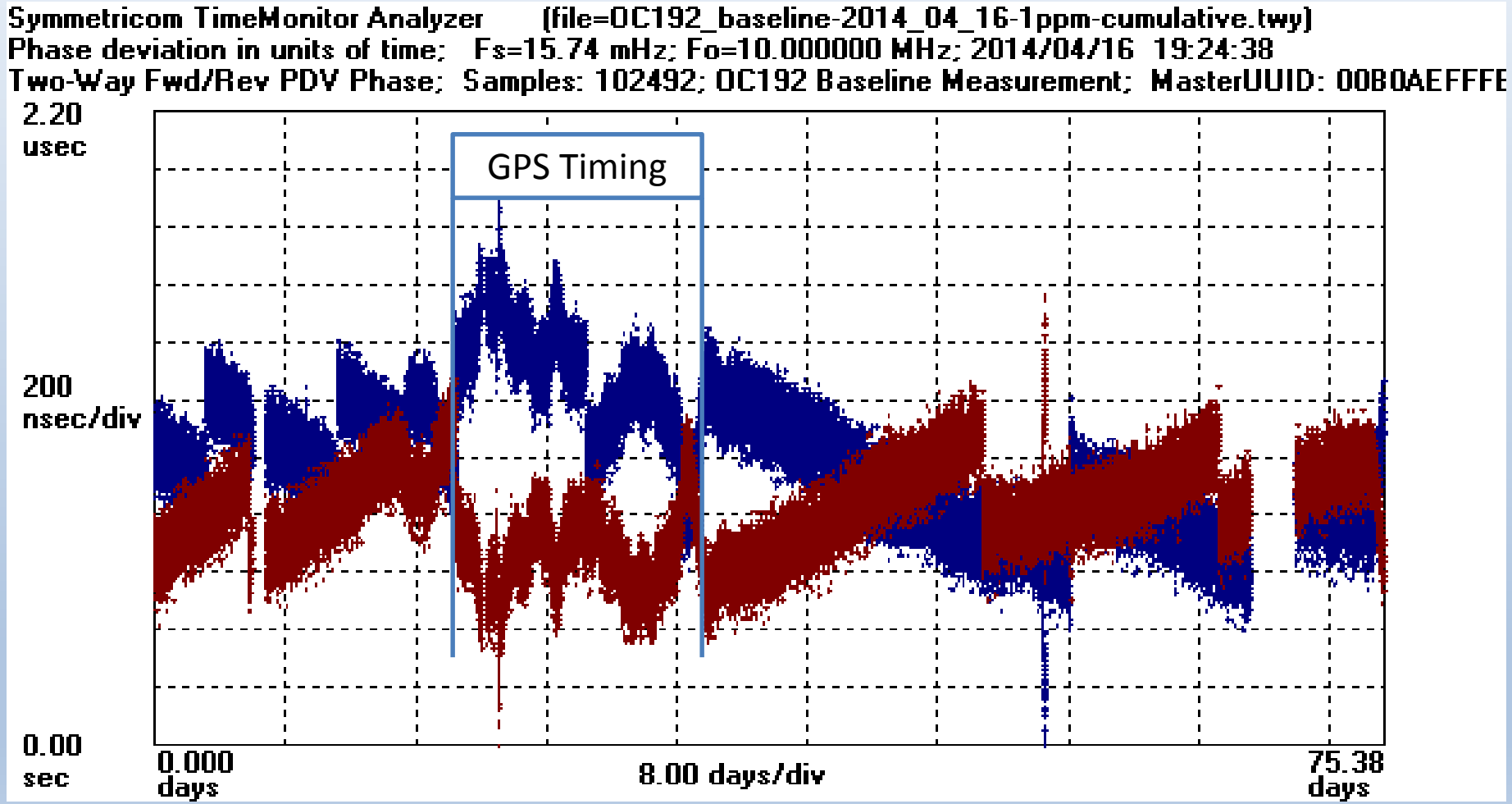
PTP Over SONET

Forward means NIST to USNO AMC
Reverse means USNO AMC to NIST

- With Cs timing of some nodes, slopes of about 50 ns/d and resets when it reaches about 300 ns
- With GPS timing, system accumulates wander – no apparent systematic

PTP Over SONET

OC192 forward (blue) and reverse (red) packet delay



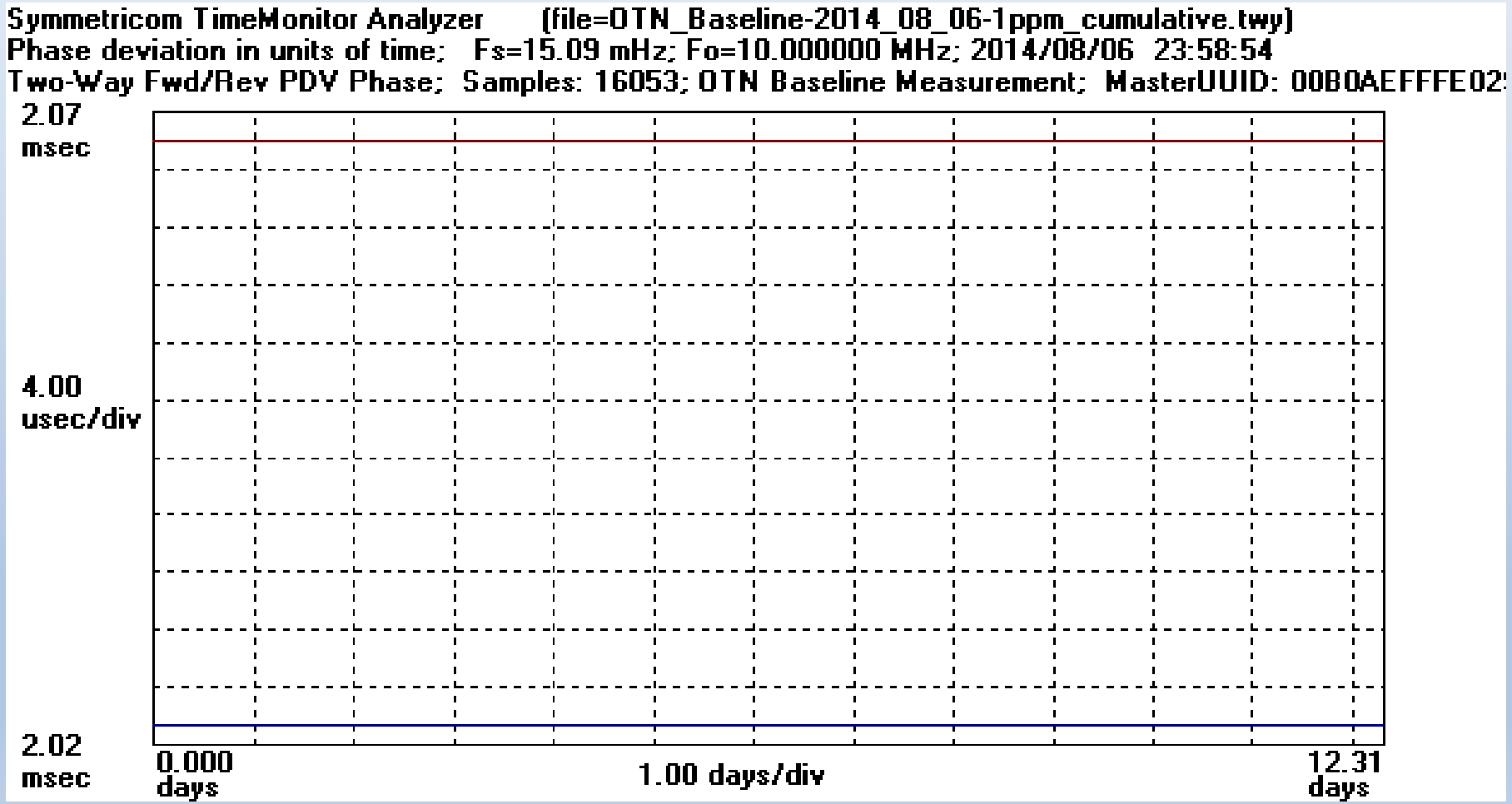
Switch to OTN Transport

- Easiest method to begin to diagnose cause of asymmetry
- Changing card determines whether the asymmetry is in the card

PTP Over OTN

12 days of data, 40.5 µs asymmetry

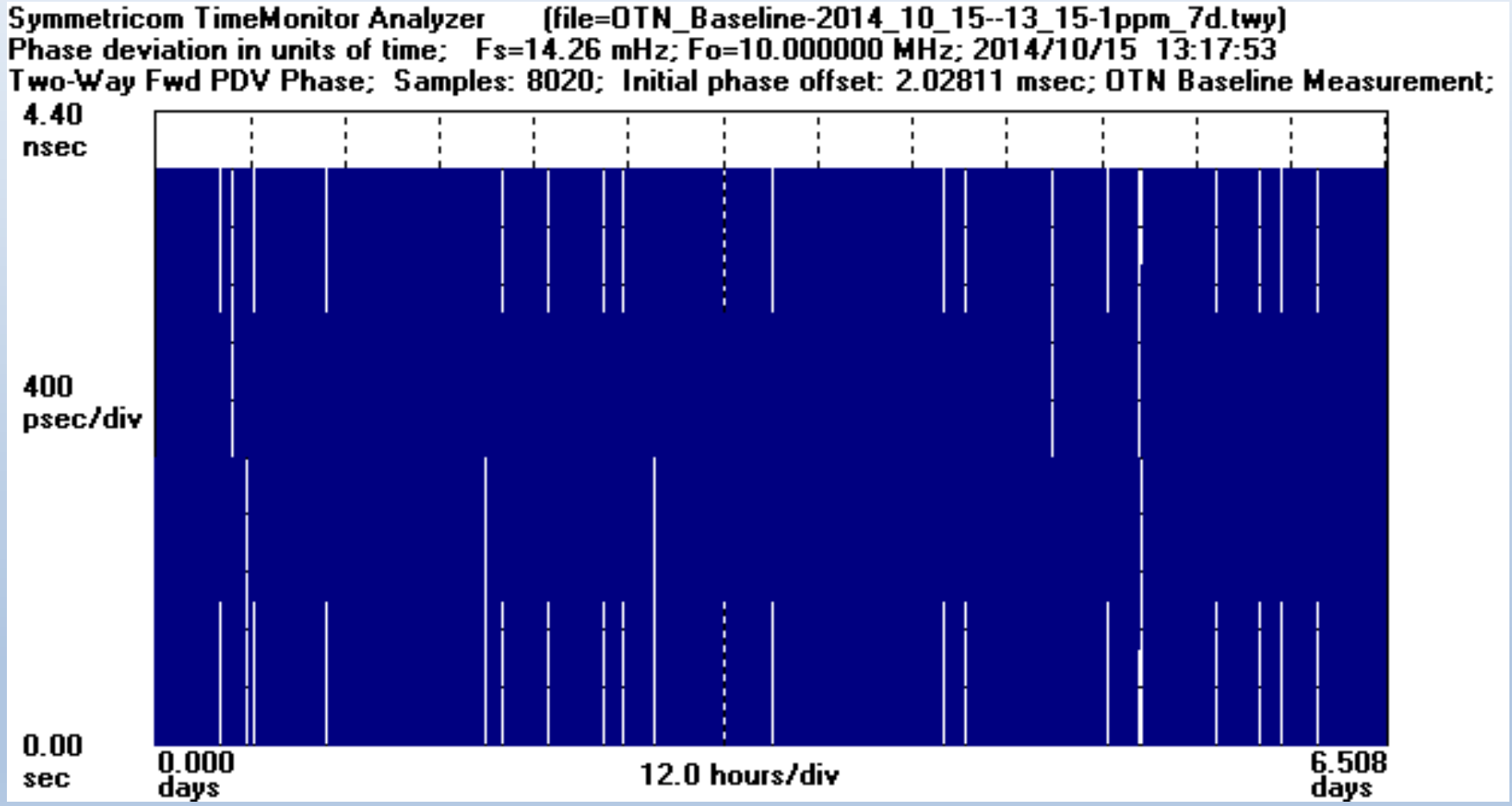
OTN forward (blue) and reverse (red) packet delay



PTP Over OTN

7 days of data; Max deviation of 4 ns (fwd) and 0 ns (rev)

OTN forward (blue) and reverse (red) packet delay



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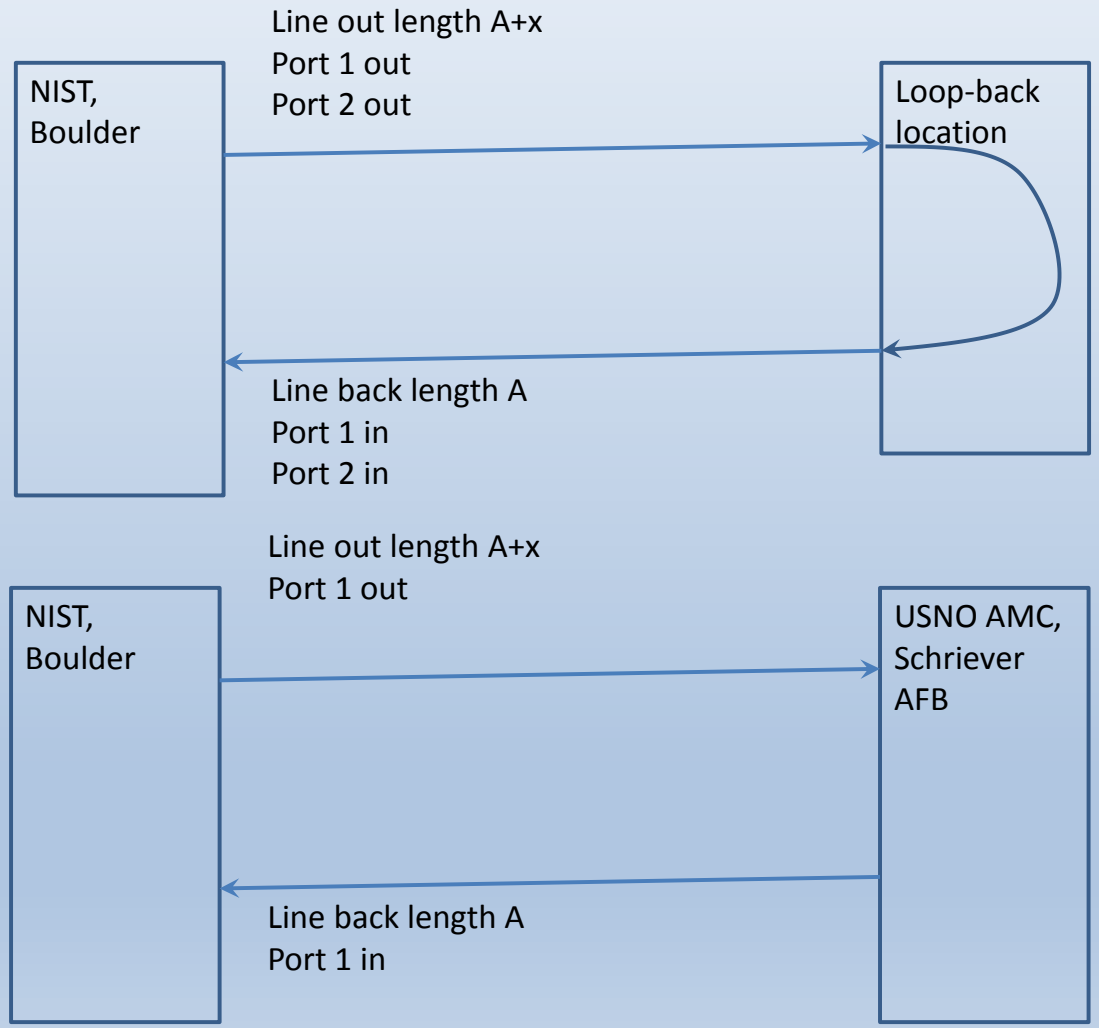
Sectionalize Circuit with Loopback

- Cause of 40 µs asymmetry difference still unknown, but likely not the card (SONET vs OTN)
- "Loopback" test to sectionalize the circuit
  - Two fibers out and back each pair going to a different port on the same PTP device
  - From Boulder lab, loopback locations: Local Boulder, Denver, Colorado Springs, Security (last office before Schriever AFB)

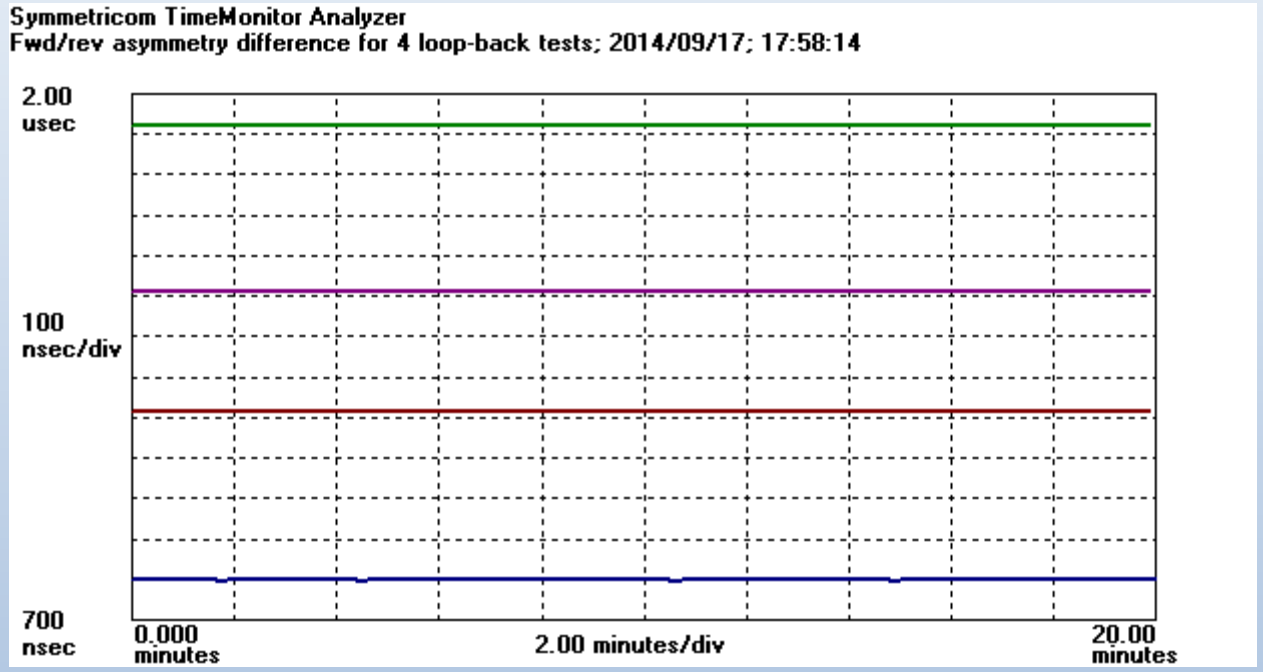
Loopback Test

The loopback test cannot measure the asymmetry of a single two-way time transfer



PTP Over OTN Loopback to Local Office

- Known random offset up to 3 µs when set up circuit at local office
  - We found 0.8, 1.2, 1.5 and 1.9 µs by closing and setting up circuit in local office



- Total delay ~ 220 µs, though circuit is loop back through about 2 miles of fiber
  - Fiber length accounts for 1-2 µs
  - Clearly most of delay is in equipment
- Max deviation ~ 4 ns

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Next Step to Place Microsemi PTP Equipment in Centurylink Offices

- Place two PTP+GPS devices, TP5000, same model as what is at NIST and USNO AMC now
- Place a TP5000 at the Denver and Colorado Springs Office
- Allow for direct two-way time transfer in three sections
  - Between NIST, Boulder and Denver
  - Between Denver and Colorado Springs
  - Between Colorado Springs and USNO AMC, Schriever AFB

Goal for This “Next Step” Experiment

- Isolate cause of 40 microsecond asymmetry
  - Perhaps find a protocol to eliminate or reduce this
- Show time transfer capabilities
  - Currently, with calibration of constant offset, using OTN transport we can maintain accuracies within 10 nanoseconds
  - Without calibration there is a 6 microsecond known random error
  - A 40 microsecond error would imply a 20 microsecond time transfer offset if uncalibrated

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Next Steps

- Results of experiment are to be published
- ATIS sync standards committee (COAST-SYNC) has a project for GPS backup
  - This experiment to show capabilities across one commercial carrier
  - Consider extending this experiment to other geographic areas or using other carriers

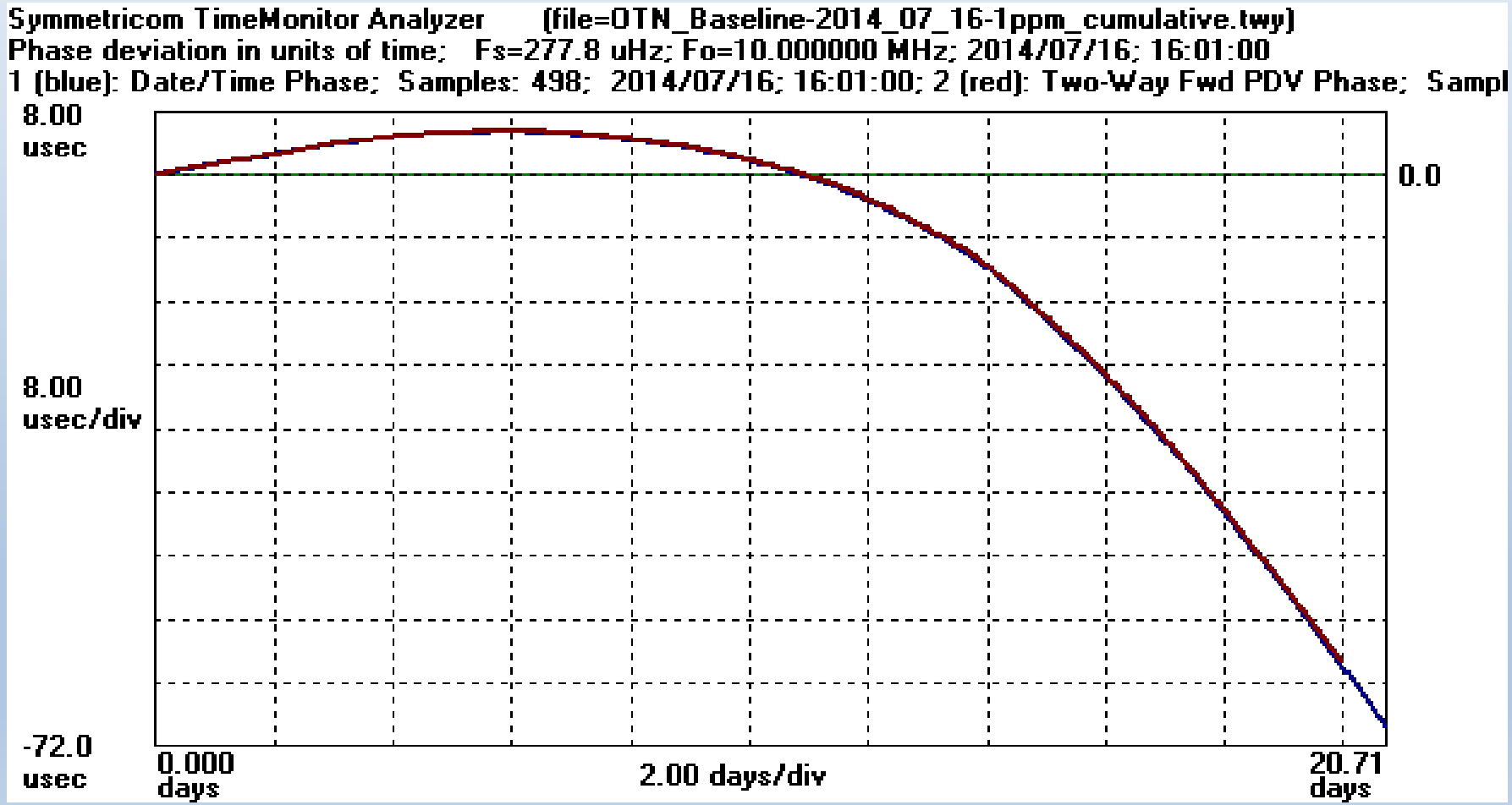
Thank You for Your Attention

Extra Slides

Sanity Check

Local measurement of unlocked master clock vs. remote measurement of master clock using PTP

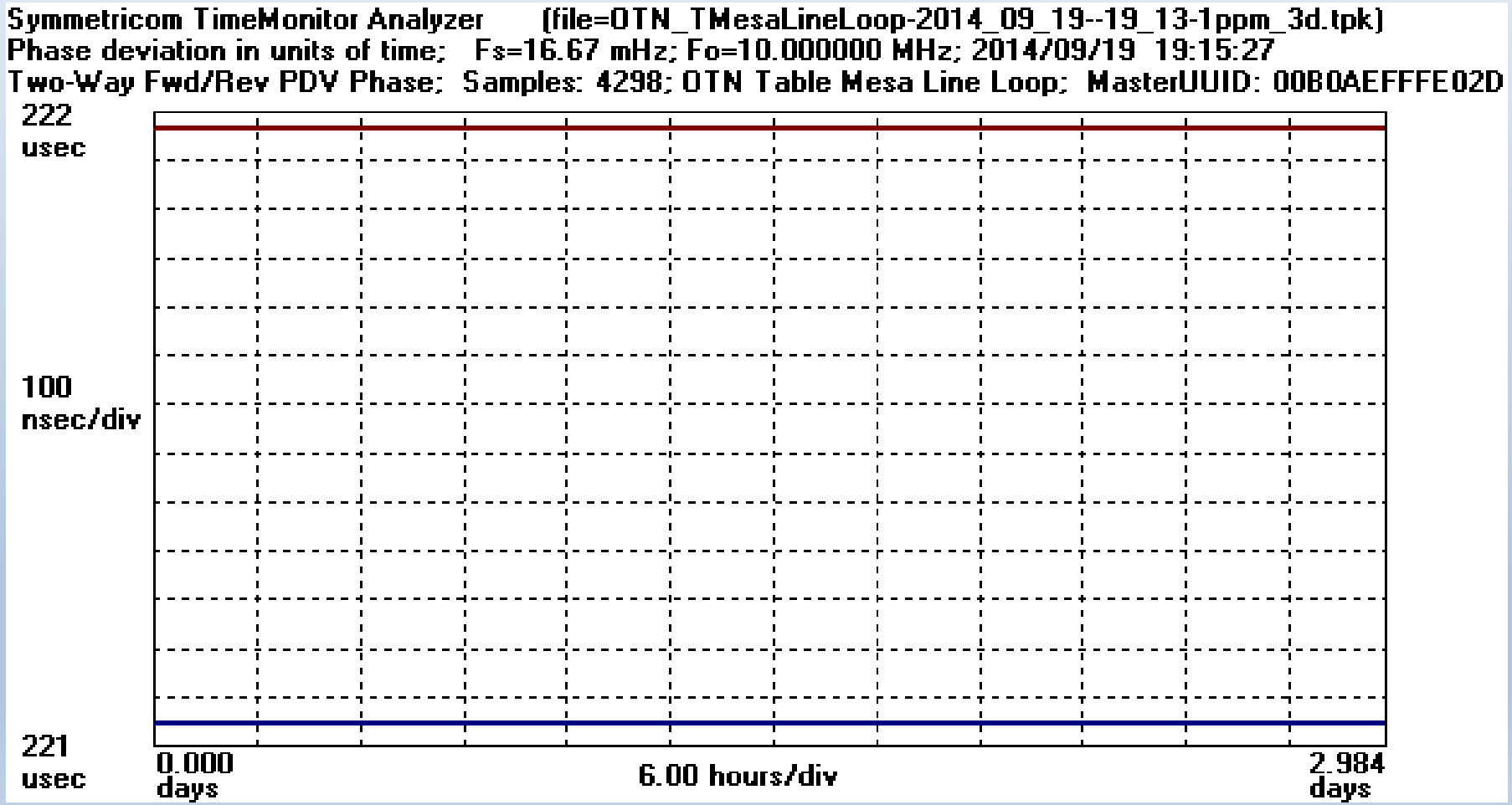
Local direct (blue) and remote via PTP FWD (red)



PTP Over OTN Loopback to Local Office

Random Offset up to 3 µs

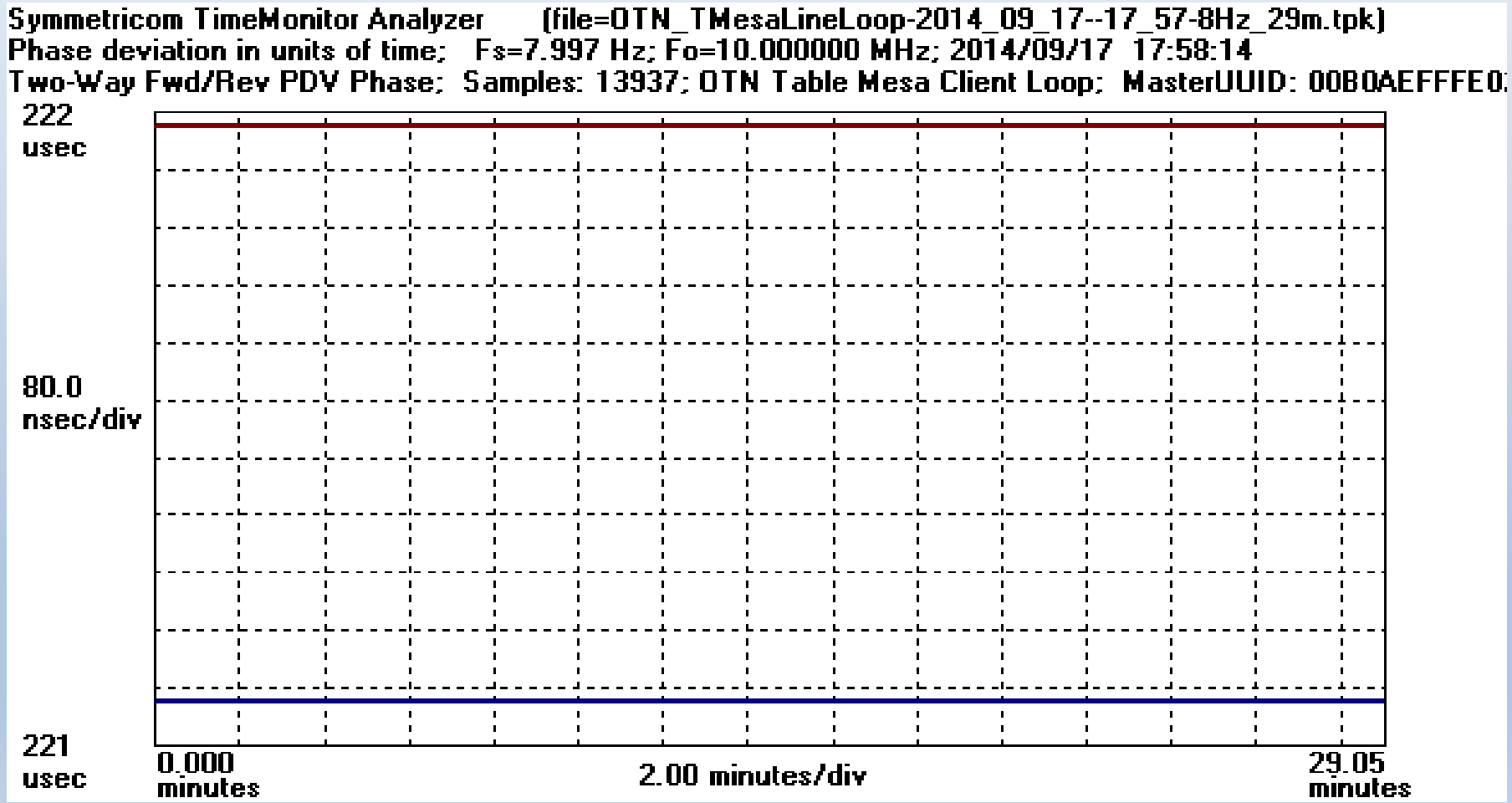
Here we have 1.2 µs



PTP Over OTN Loopback to Local Office

Random Offset up to 3 µs

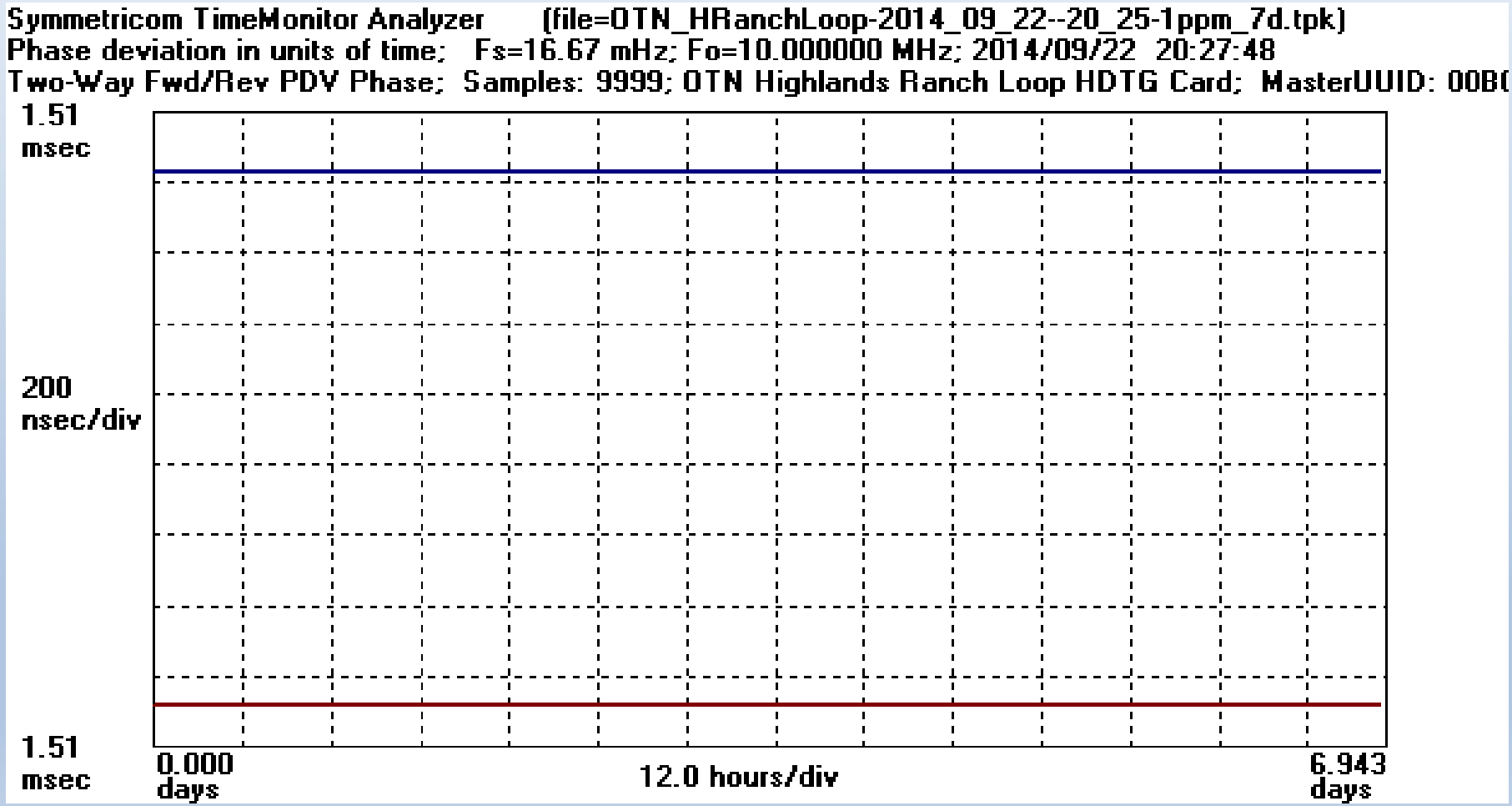
Here we have 0.8 µs



PTP Over OTN Loopback to Denver Office

Known Random Offset up to 3 µs

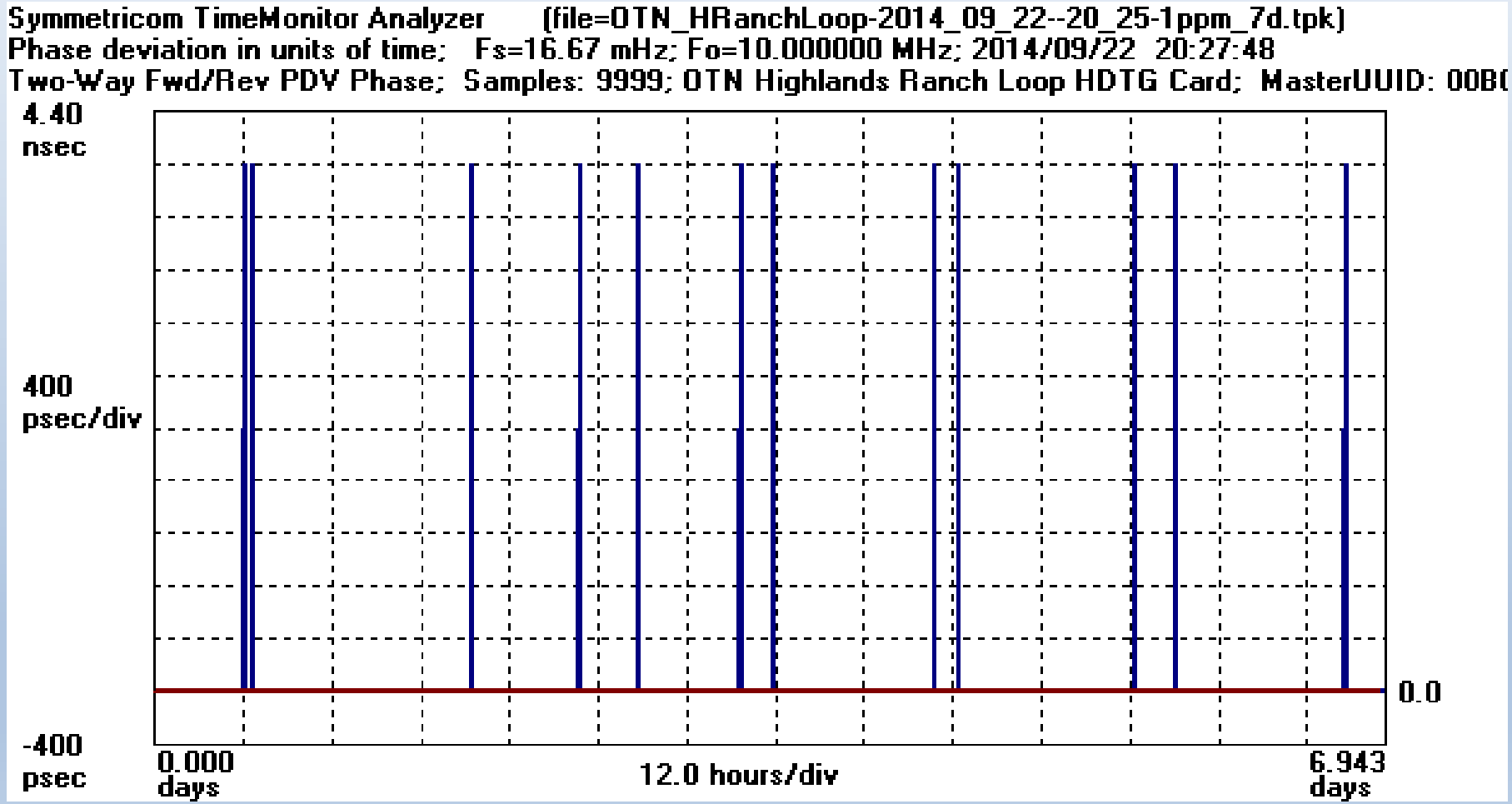
Here we have 1.5 µs



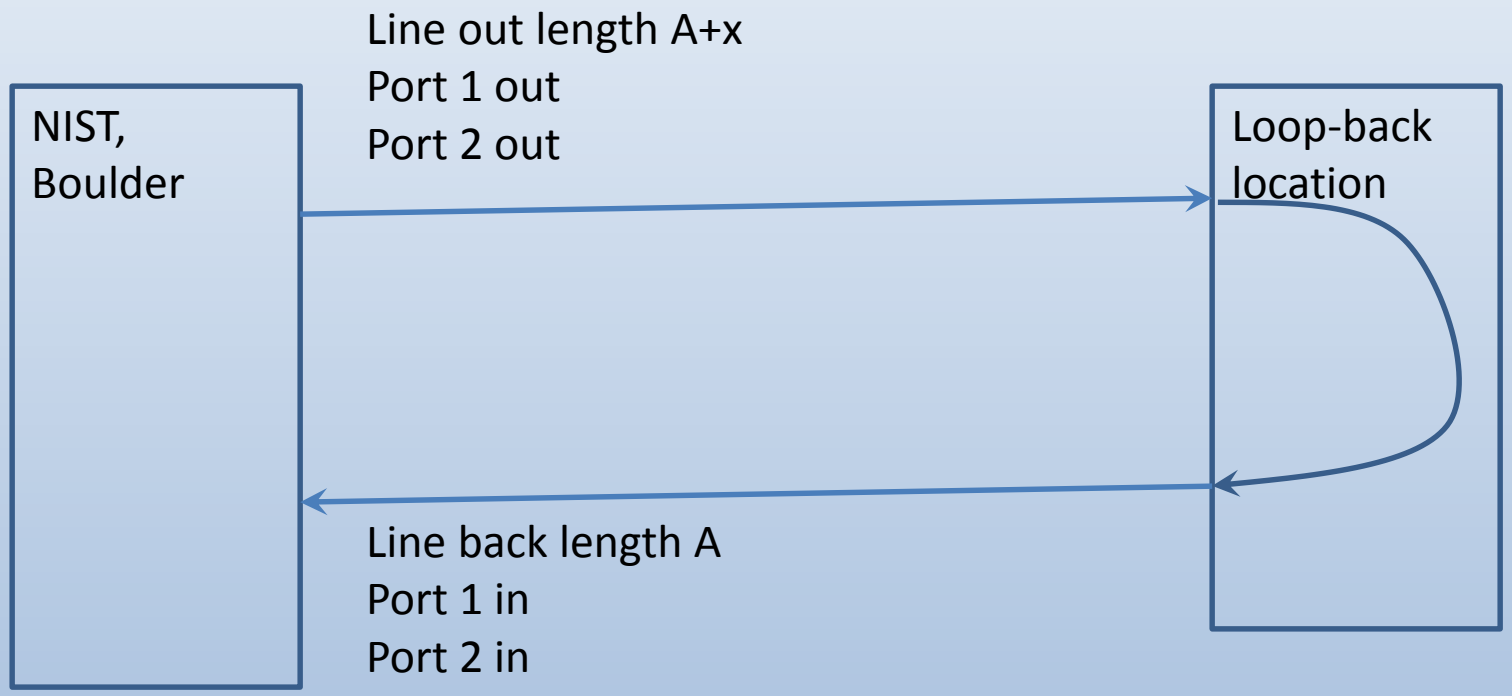
PTP Over OTN Loopback to Offices Beyond Boulder: Denver, CO Springs, Security

- Asymmetry of 1.5 µs probably due to local office
- Total delay ~ 1.5 ms round-trip
  - Note that total one-way delay NIST to Schriever AFB was about 2 ms
- Max deviation ~ 4 ns over 4 days
- The loopback test cannot measure the asymmetry of a single two-way time transfer

PTP Over OTN Loopback to Denver Office
Max Deviation = 4 ns over 7 d



Loop-Back Test



For loop-back we are emulating time transfer between two locations by using two ports on the same device in NIST. Both the loop from Port 1 and from Port 2 measure a delay of 2A+x, hence the difference between length A and length A+x is not seen.

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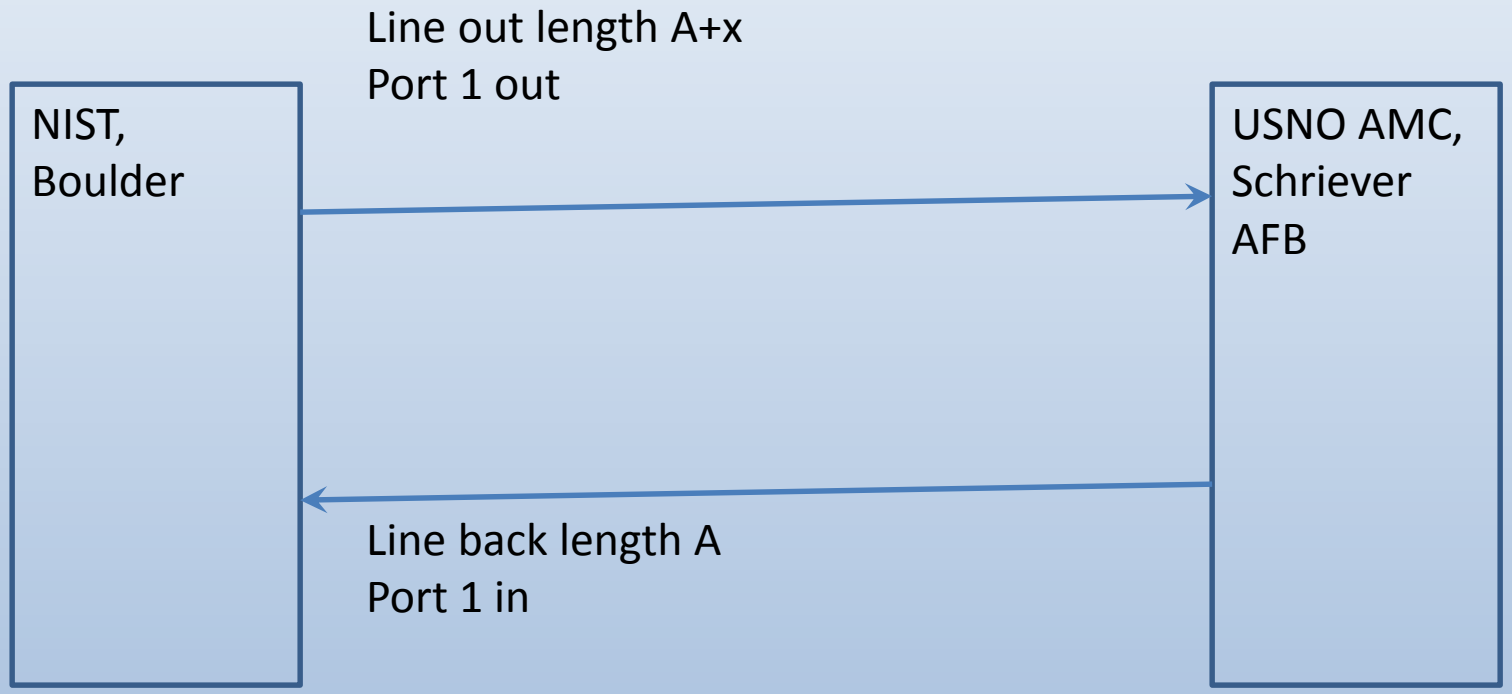
One-Way Measurement
NIST, Boulder to USNO AMC, Schriever AFB



Because NIST and USNO both have UTC synchronized within 10 ns, we measure the one-way delays in each direction. We see the difference x between the path of length A+x and the path of length A. We have seen a differential x of 40 µs.

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Remaining Issues for PTP over Fiber

- Sending PTP signals over long distances directly from a UTC source requires further testing
  - Native Gbit Ethernet networks with routers
    - With and without on-path support
    - Asymmetry issues
  - Other potential transports

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Expectations

- Time transfer accuracy will depend on the length of transport and number and type of network elements, as well as any impediments in signal transport
- Better than 100 ns *stability* probable over short links, and short times
- Accuracy depends on reducing or calibrating asymmetry – hope for sub microsecond

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