Extended Time Holdover – A Bit of a Challenge

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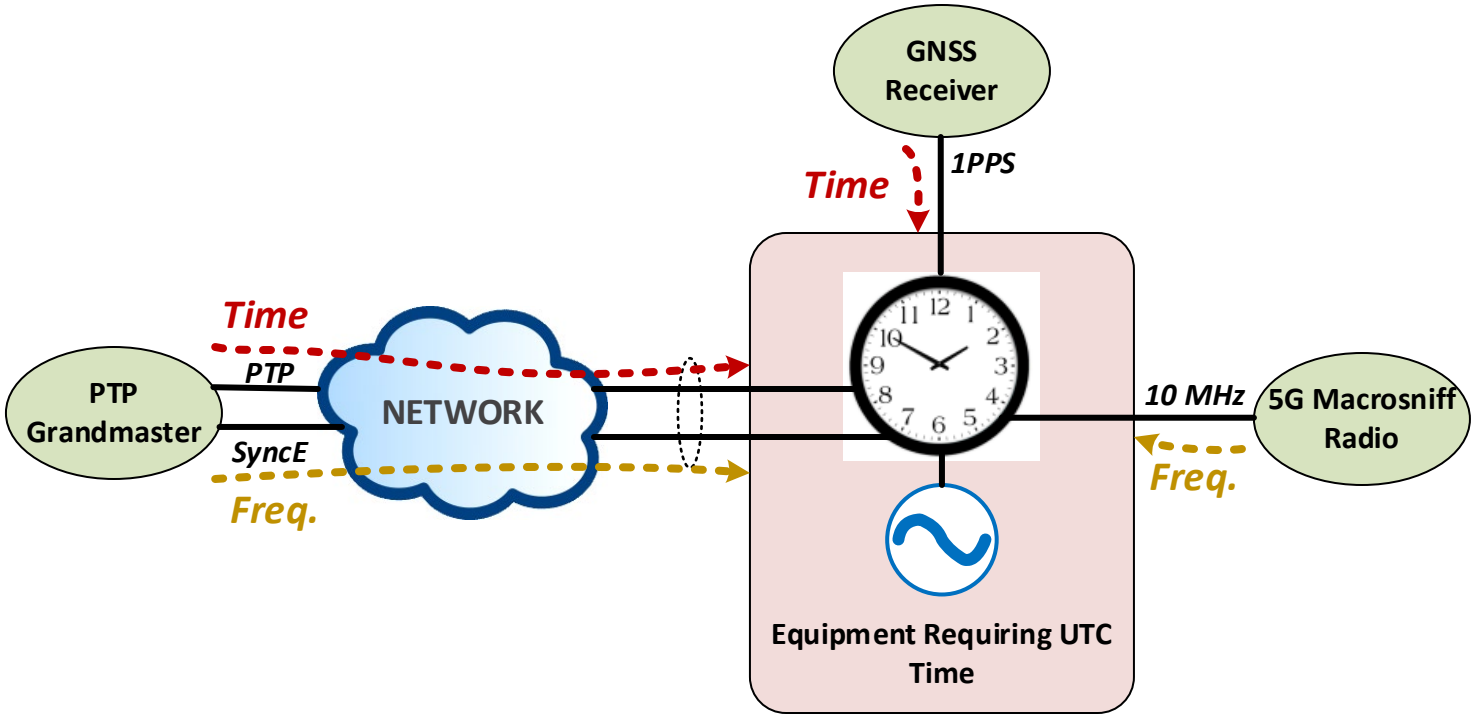
A Holdover Refresher

- A well-designed system has multiple external sources of time or frequency
  - Used individually or combined
- If one fails, switch to another
- If all time sources fail then use a frequency-only source to keep local clock ticking
- Only if every external source fails do you need to go into holdover
  - Maintain time based on your local oscillator



Holdover is your synchronization choice of last resort … but still needs to be good enough

Do I Even Need Holdover?

Scenario 1 – A carrier-grade, pole-mounted macro base station

- Has local GNSS receiver for primary sync
  - Antenna has 360° clear view of the sky
- Backup sync comes from carrier-provided PTP
  - Well architected sync network
    - Full-timing support with boundary clocks at every node
    - Redundant, geographically separated, grandmasters
- Primary GNSS will be about as reliable as GNSS can be
  - … which generally isn't good enough – let's say 99%
  - But we have PTP as a backup
    - Redundant grandmasters mean that total PTP failure is unlikely
- Holdover will only be needed if 1) GNSS is not available, and 2) No PTP master is available – implies failure of transport
  - Pretty unlikely and quite probably would also result in total loss of data transport

We probably don't need to lose sleep over providing extended holdover support here!

Do I Even Need Holdover?

Scenario 2 – A in-office femtocell in the middle of a city-center highrise

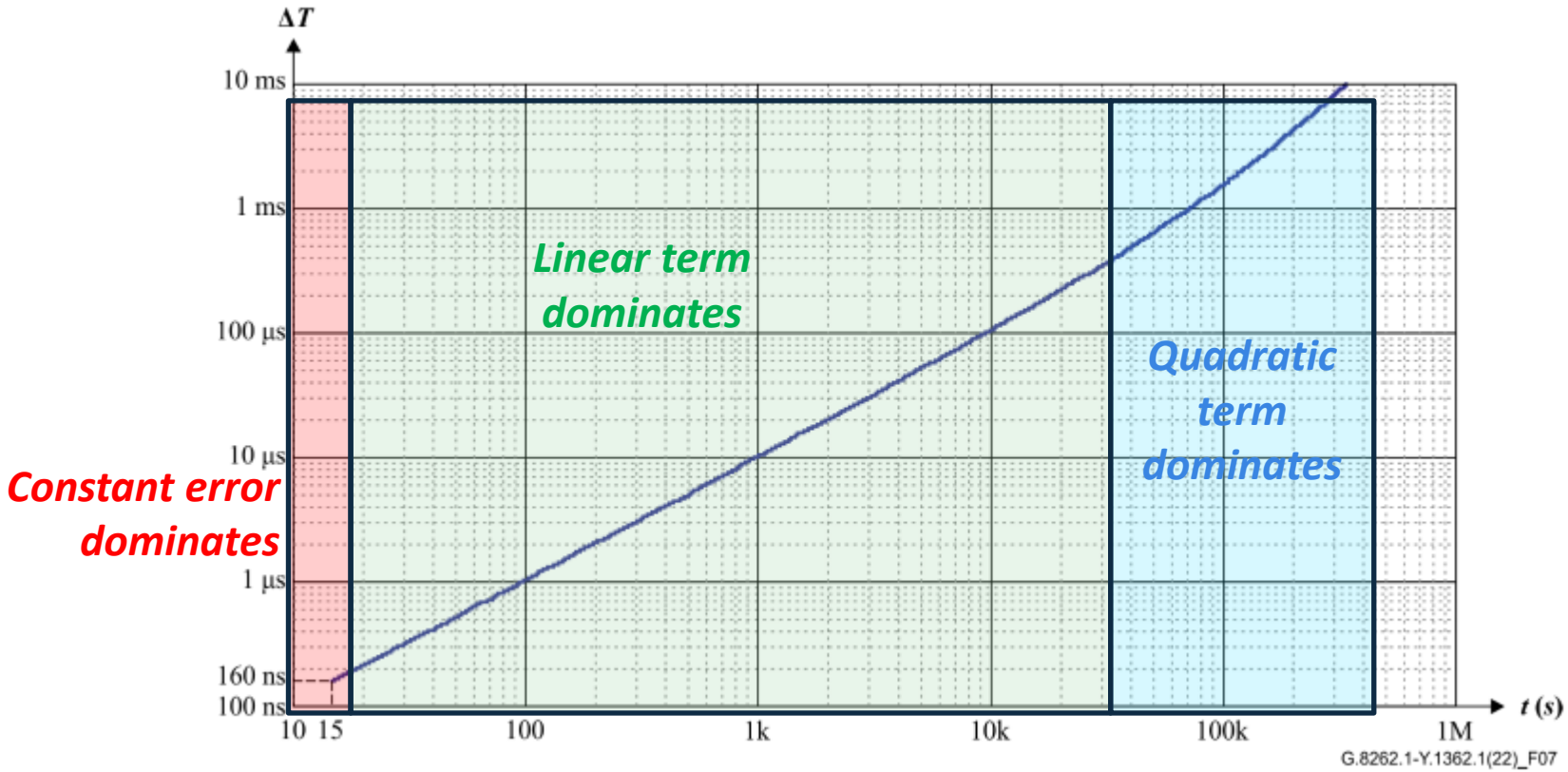
- Has local GNSS receiver for primary sync
  - Patch antenna that keeps falling off stuck to inside of window
- Backup sync from macro-sniffing carrier 5G network
  - Sniffing hardware is shared with local radio unit
    - Have to switch primary radio off to grab sync
    - Which can only be done very occasionally
- Primary GNSS is probably pretty flakey
  - … poor antenna, limited sky view, urban canyon multipath, jamming etc.
  - Hence very likely to need macrosniff as sync backup
    - But can only do this, say, a few times a day in order to limit disruption
- Holdover is now a keep part of the sync strategy
  - Need for holdover likely decoupled from availability of actual data link
  - Must provide holdover for period between macrosniffs – could be many hours

A definite case of needing enhanced holdover in a cost-sensitive environment

Modeling & Specifying Holdover

$$\Delta T(t) = at + \frac{b}{2}t^2 + c$$

Time error *Linear term* *Quadratic term* *Constant error*



Where do the Errors Come From?

$$\Delta T(t) = at + \frac{b}{2}t^2 + c$$

Time error — c

Linear term — at

Quadratic term — $\frac{b}{2}t^2$

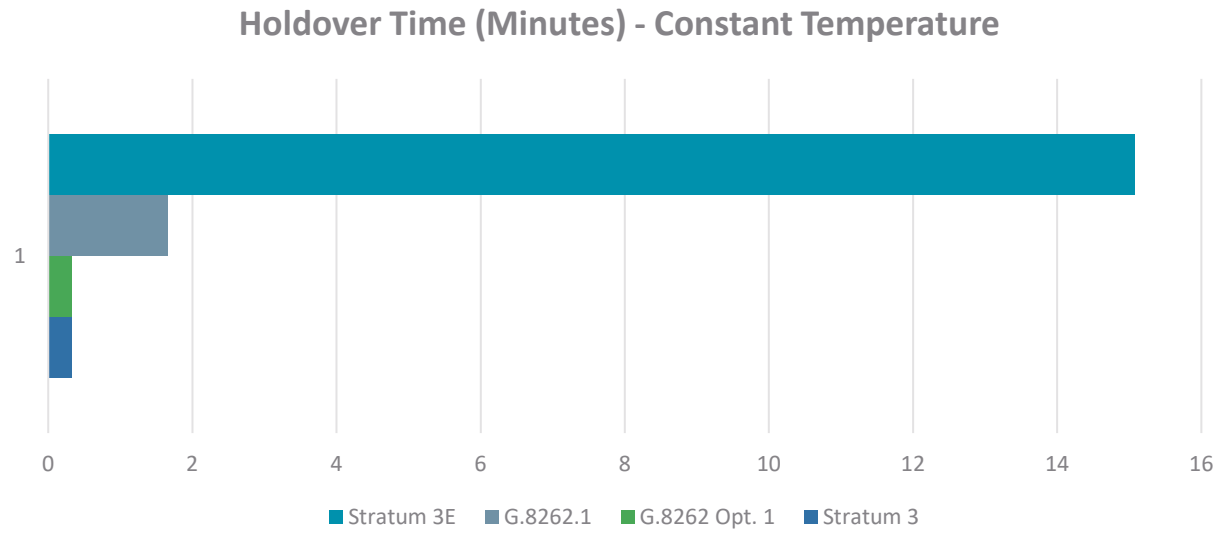
Constant error — c

- **Constant error** – Phase transient when entering holdover, or shortly there after
  - Independent of local oscillator
  - Typically, insignificant outside of initial short period (often not considered holdover even)
- **Linear term** – Frequency error that is either constant or averages to a constant
  - Frequency error when establishing holdover mode (not directly oscillator related)
  - Frequency change due to temperate (directly related to oscillator)
- **Quadratic term** – Frequency error that changes linearly with time
  - Largely due to oscillator aging effects

OCXO-type oscillators already do a good job of managing the temperature contribution to the linear term

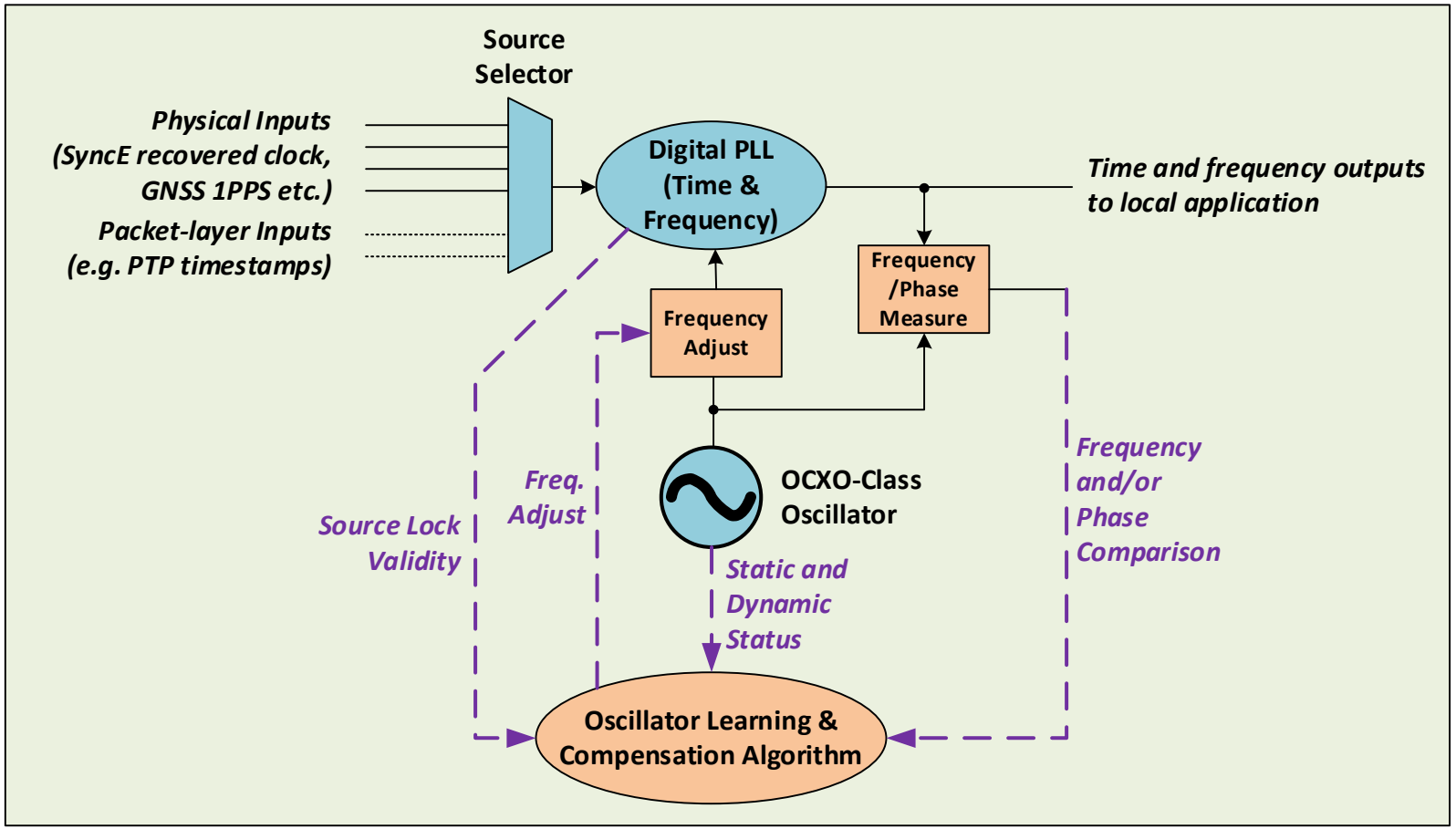
Time Holdover – A Big Challenge

- Many of today's applications call for holdover to maintain time to within ~1 µs for 8, or even 24, hours (that's 480/1440 minutes)
  - Yet designers still think in terms of holdover specs from frequency-only standards



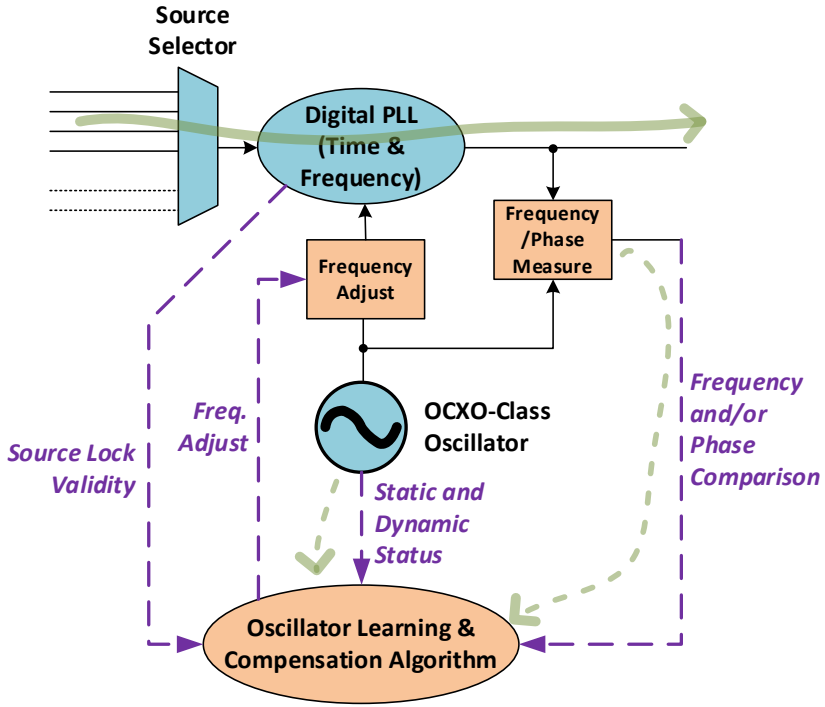
Meeting G.8262.1 or even Stratum 3E holdover requirements doesn't come even close to meeting these time holdover requirements – we need a strategy

Strategy #1: Aging Learning

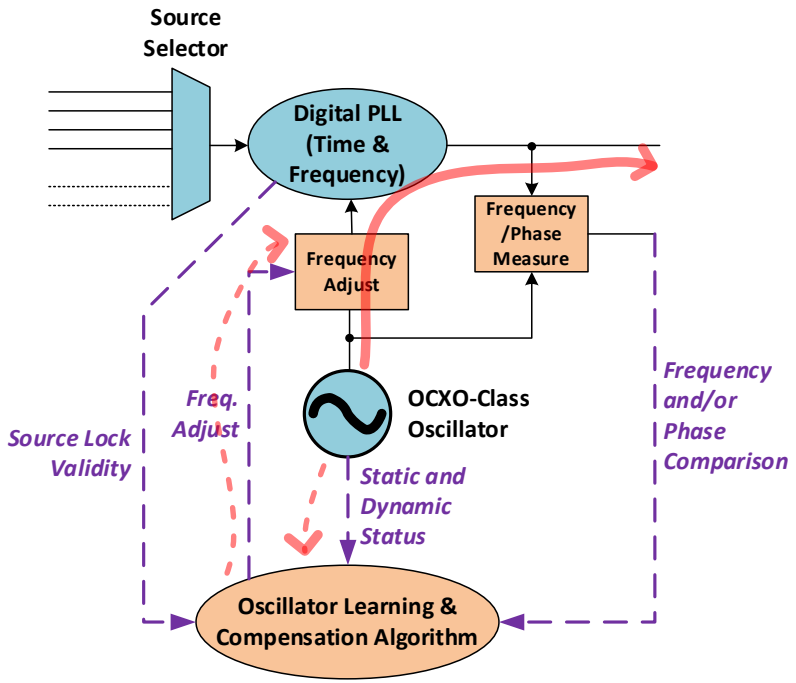


Supplement existing synchronization solution with high-resolution frequency/phase measurement and reference frequency adjust capabilities, and some clever software

The Learning & Correction Process



- Outputs are derived from external source
- Periodic frequency or phase measurement again local oscillator and externally-locked timebase performed
- Learning algorithm uses these measurements in conjunction with other data (temperature etc.) to determine aging behavior over time

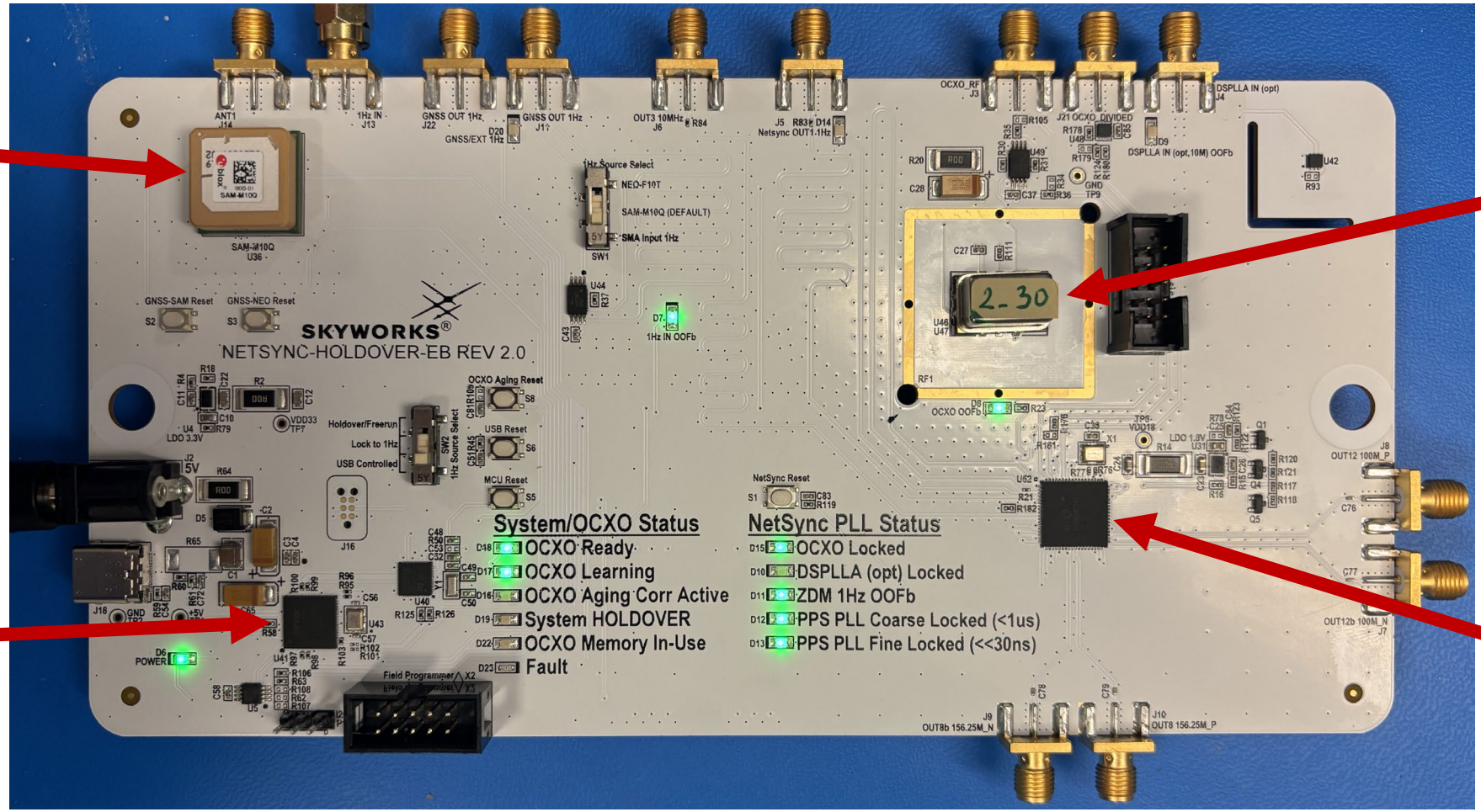


- Outputs are derived from local oscillator
- No external reference so no further measurements can be made
- Instead, algorithm switches to a control mode and uses behavior previously learnt, along with live data (temperature etc.) to adjust output frequency to compensate for estimated drift

The Test Setup

GNSS Receiver for learning reference

CPU running learning algorithm



Smart OCXO

Digital PLL

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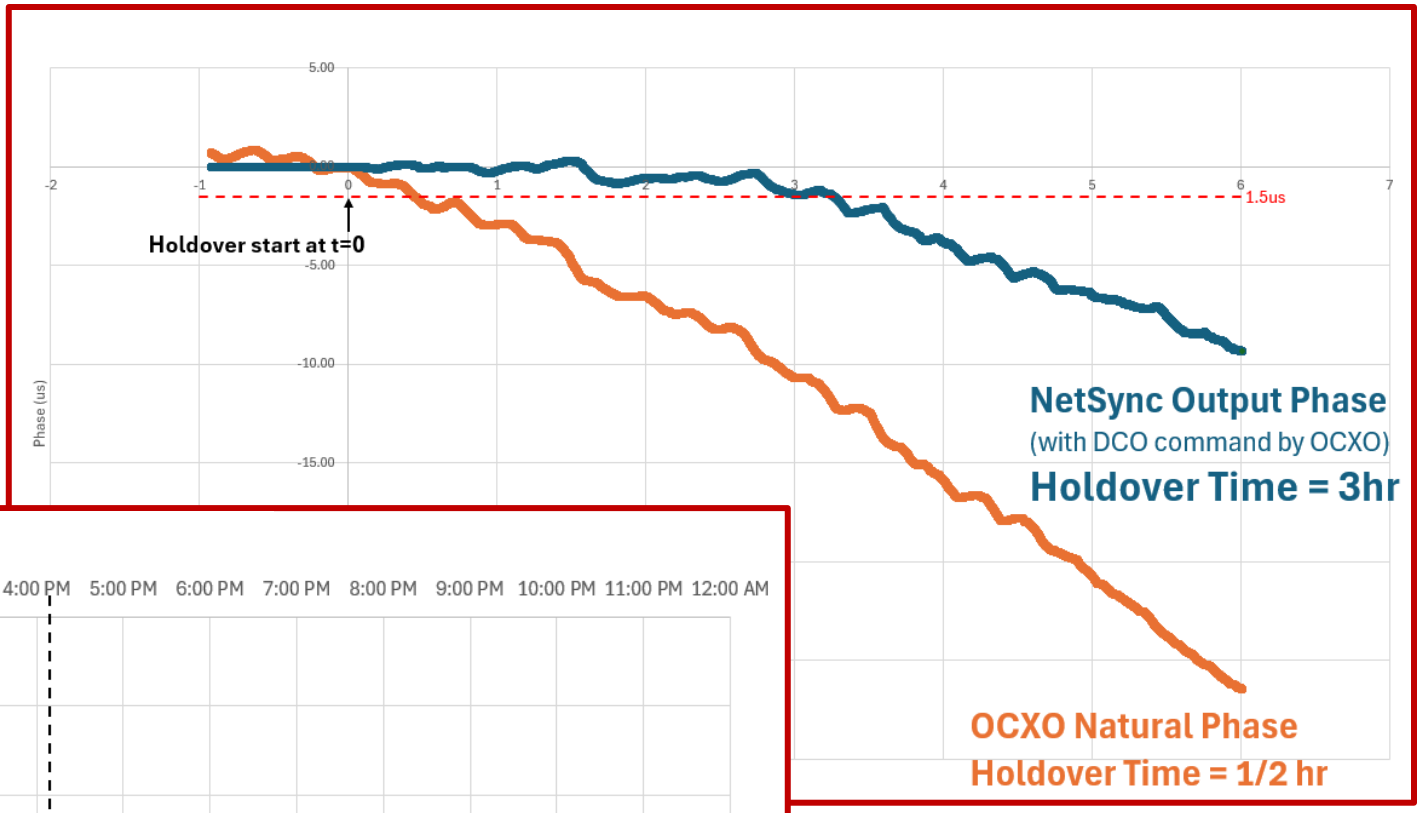
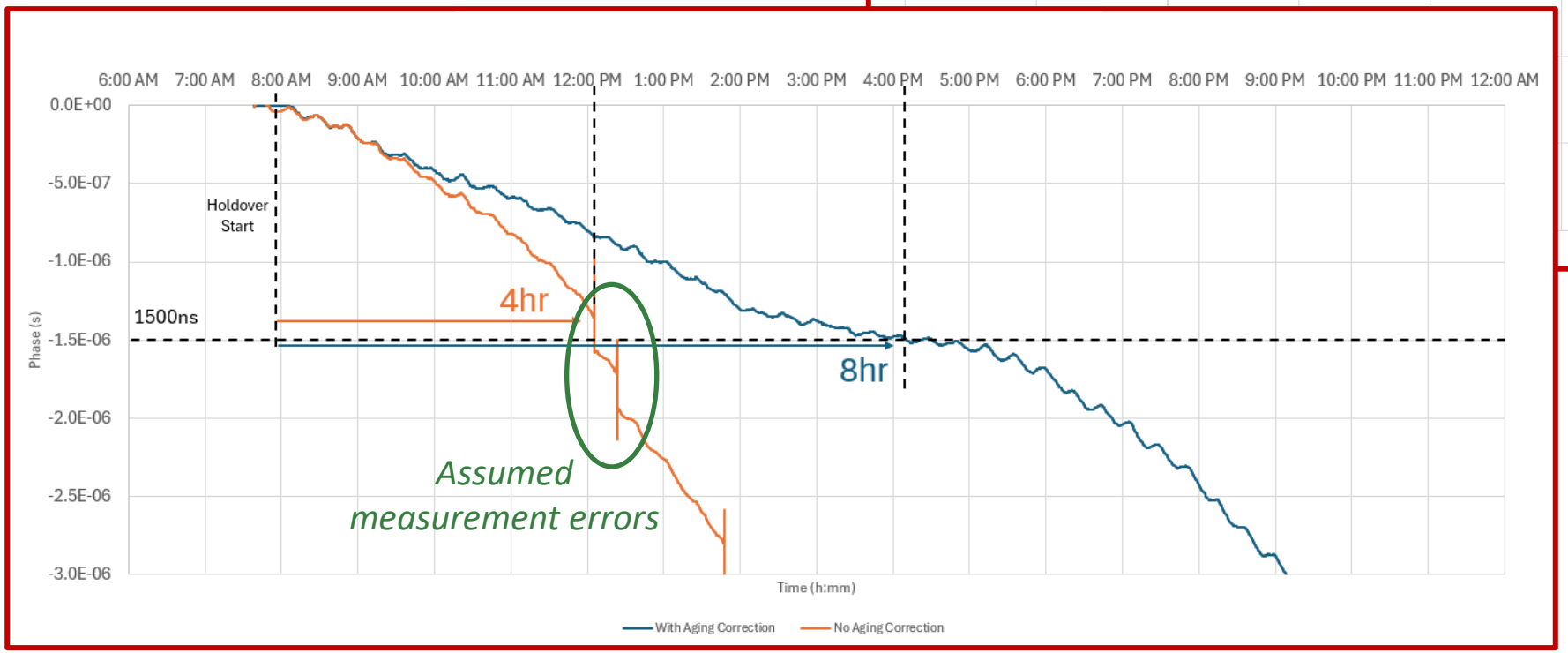
The Results

Oscillator 1 – lower cost, lower performance





Oscillator 2 – higher cost, higher performance, but…

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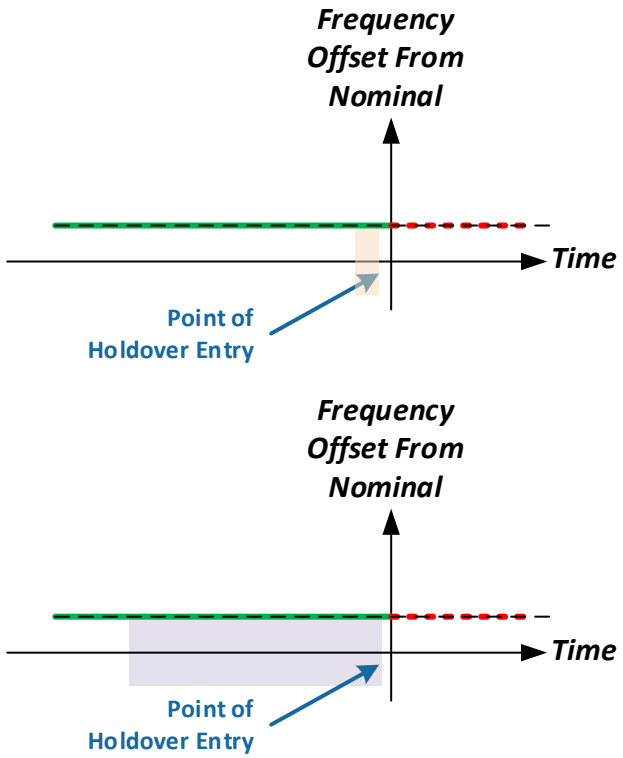
Strategy #2: Improving Accuracy at Holdover Entry

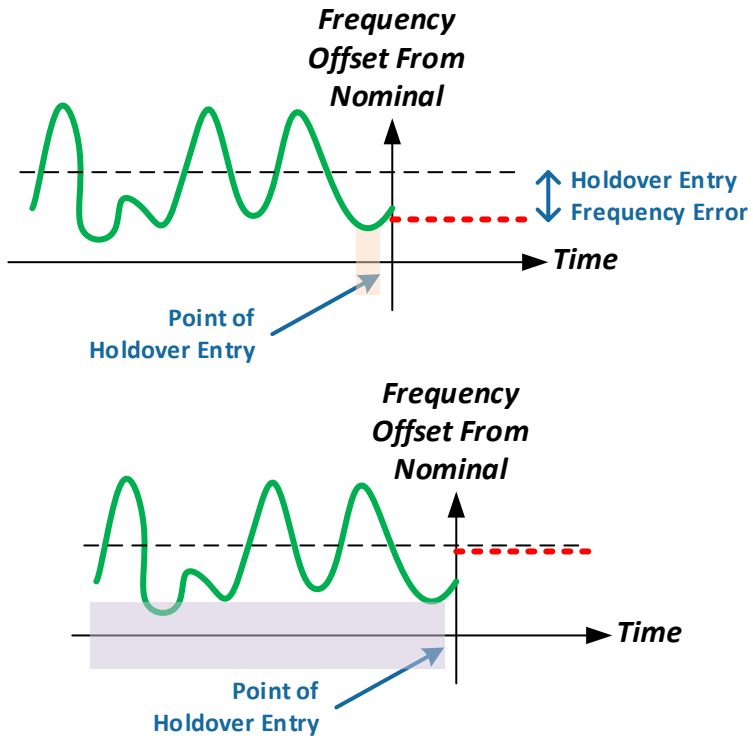
… When you have a perfect oscillator

When input has no noise:



No dependency on holdover averaging period

For a real input with noise:



Averaging time matters – needs to be much longer than noise cycle period

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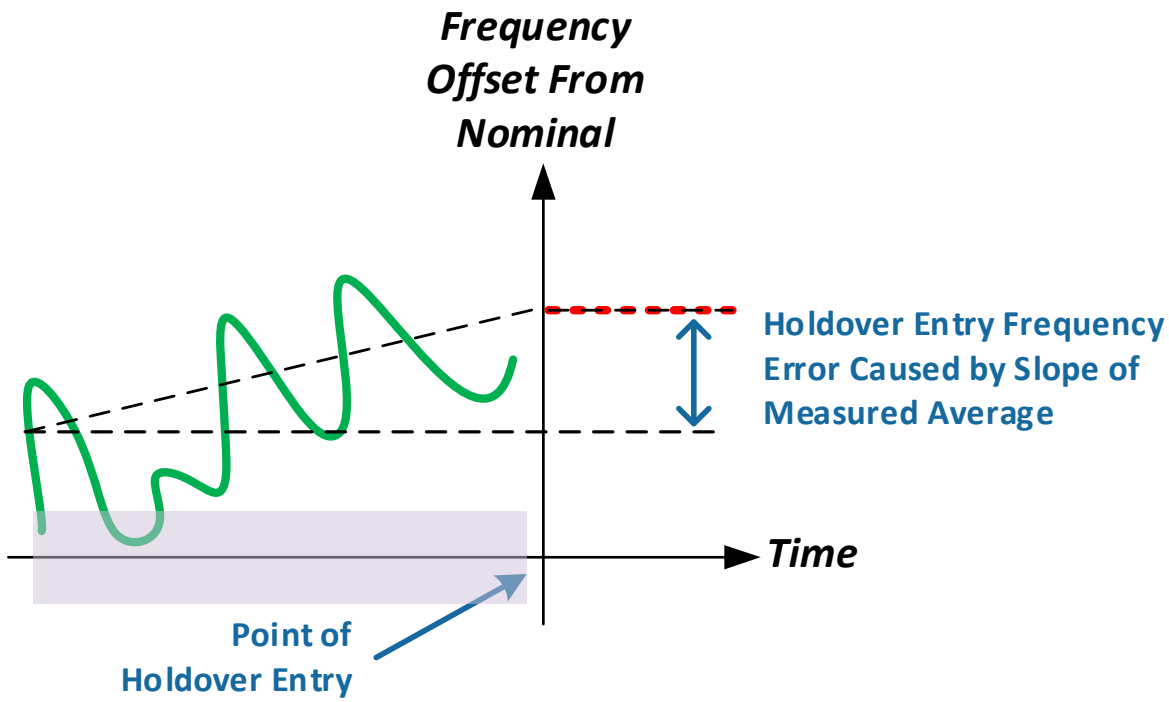
But There's Never a Perfect Oscillator

- We know we need a long averaging period to mitigate input noise (wander)
  - But then local oscillator aging will skew the average



- Need to take into account aging effect of oscillator
  - Can do this based on output from the learning algorithm
  - Might also need to consider other oscillator noise sources

Summary

- In many cases it's possible to avoid the need for holdover altogether
- But if you do need holdover, don't underestimate the challenge
  - Can't rely on frequency-only era standards to help much with time holdover
  - You will need to invest both money and time
    - Money: Start with a realistic oscillator – A <$5 TCXO will never give you 24 hours holdover!
    - Time: Develop good algorithms for:
      - Temperature compensation (oscillator vendor)
      - Aging compensation (oscillator vendor with support from network synchronizer PLL)
      - Holdover entry frequency accuracy (network synchronizer PLL vendor)
  - But it's not an impossible goal

Remember, holdover isn't just a tick box on an RFP

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