What time is it?

GPS Clocks, Leap Seconds, and the Impact on Synchrophasor Data

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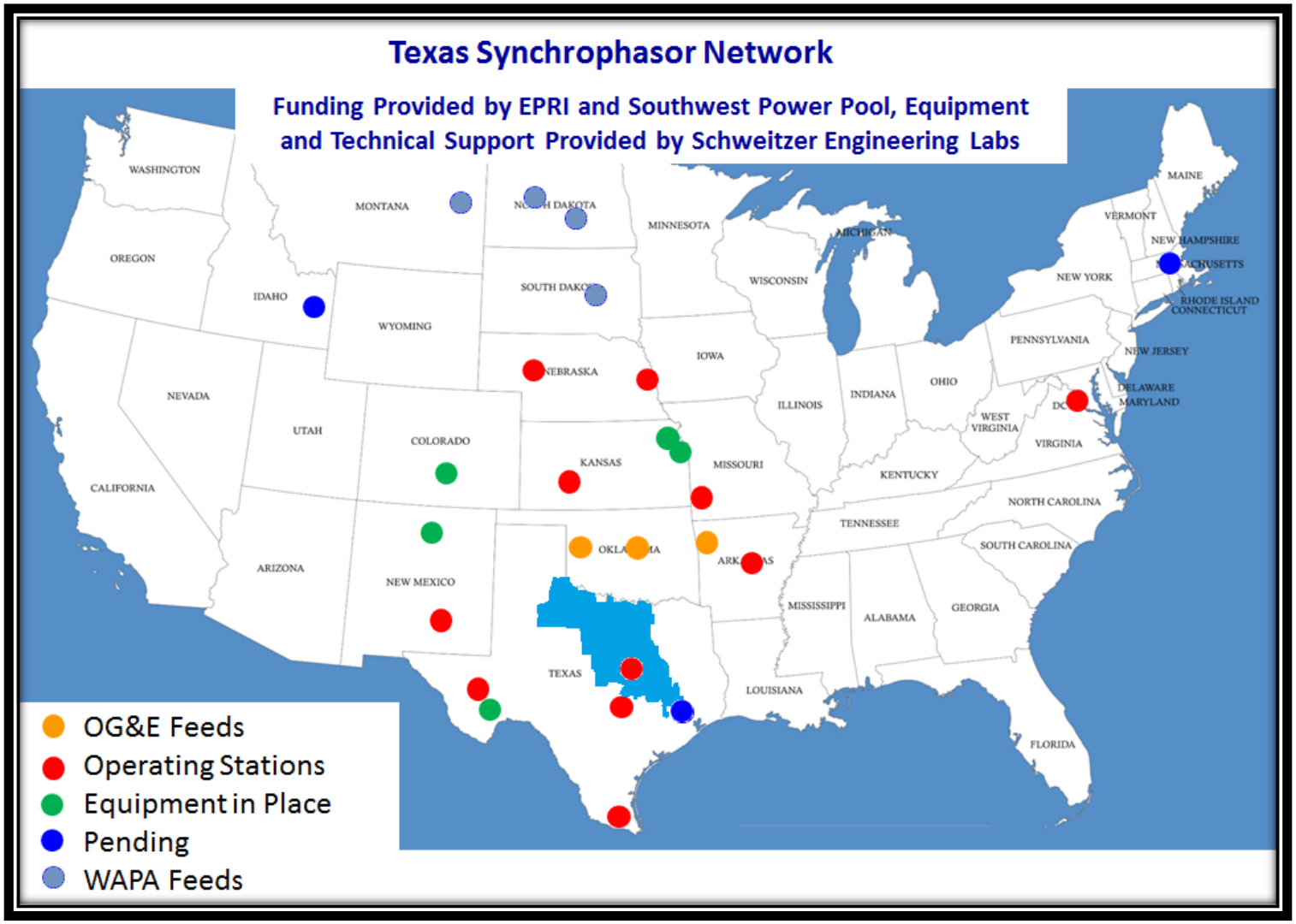
Introduction



Outline

- Time – GPS vs. UTC and some history
- Leap Seconds – What, When, Why?
- Our Problem
- December 24-25 Observations
- December 31-January 1 Observations
- Conclusion

GPS vs. UTC

GPS Time originates from an atomic clock at the US Naval Observatory, and began on January 6, 1980 [1].

GPS Satellites each contain 4 cesium atomic clocks that are synchronized to this time. [3]

Beginning in January of 1972, the UTC second is kept as close as possible to the standard set by the cesium atom.

UTC is a ‘compromise time scale’ [2] that changes due to instabilities in the earth’s rate of rotation.

Why Leap Seconds?

UT1 (non-uniform Earth Time) and UTC (Universal Coordinated Time) were synchronized January 1, 1958. The tracking method changed in 1972 when leap seconds were introduced.

When the deviation between UT1 and UTC reaches 0.9 seconds, the International Earth Rotation and Reference Systems Service (IERS) will announce the necessity for a leap second.

There have been 28 leap seconds since 1972.

GPS does not leap; since GPS was introduced in 1980, there have been 18 leap seconds.

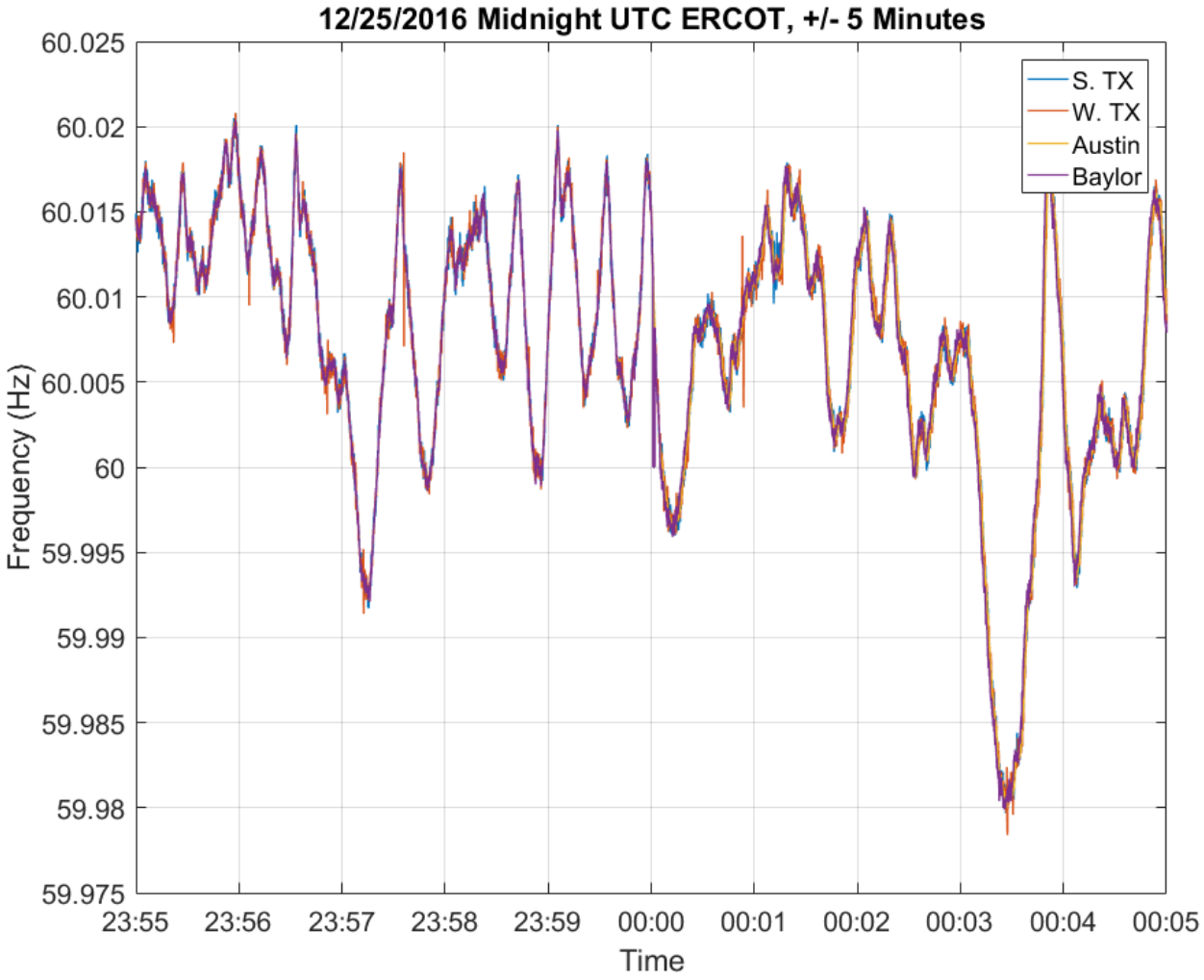
Leap seconds typically occur at the end of June or end of December.

So what's the big deal?

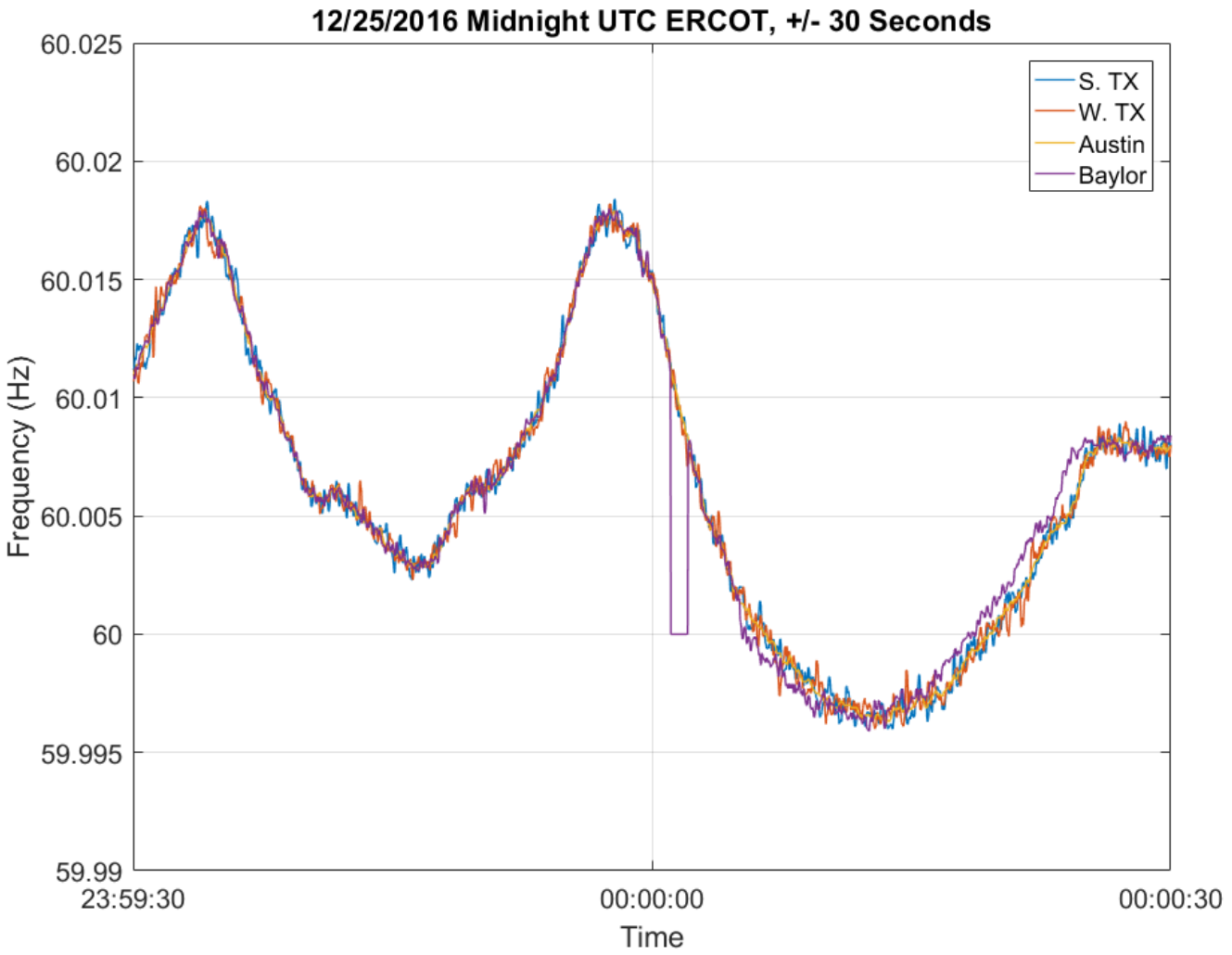
Email from Dr. Grady with "something's wrong with the data" just after Christmas Day…

Baylor-run sites were not the only sites affected… Numerous sites were impacted.

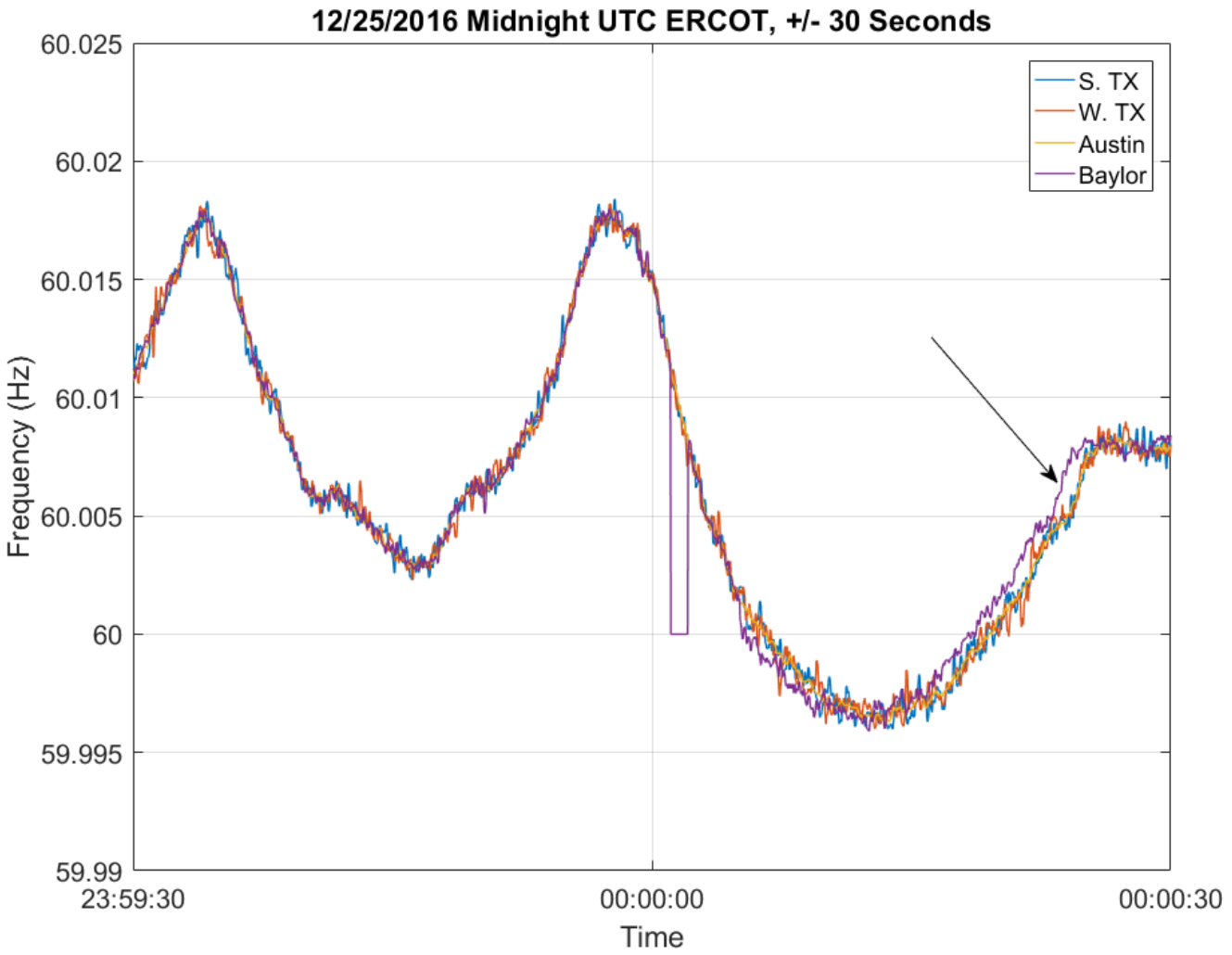
Christmas Eve Frequency



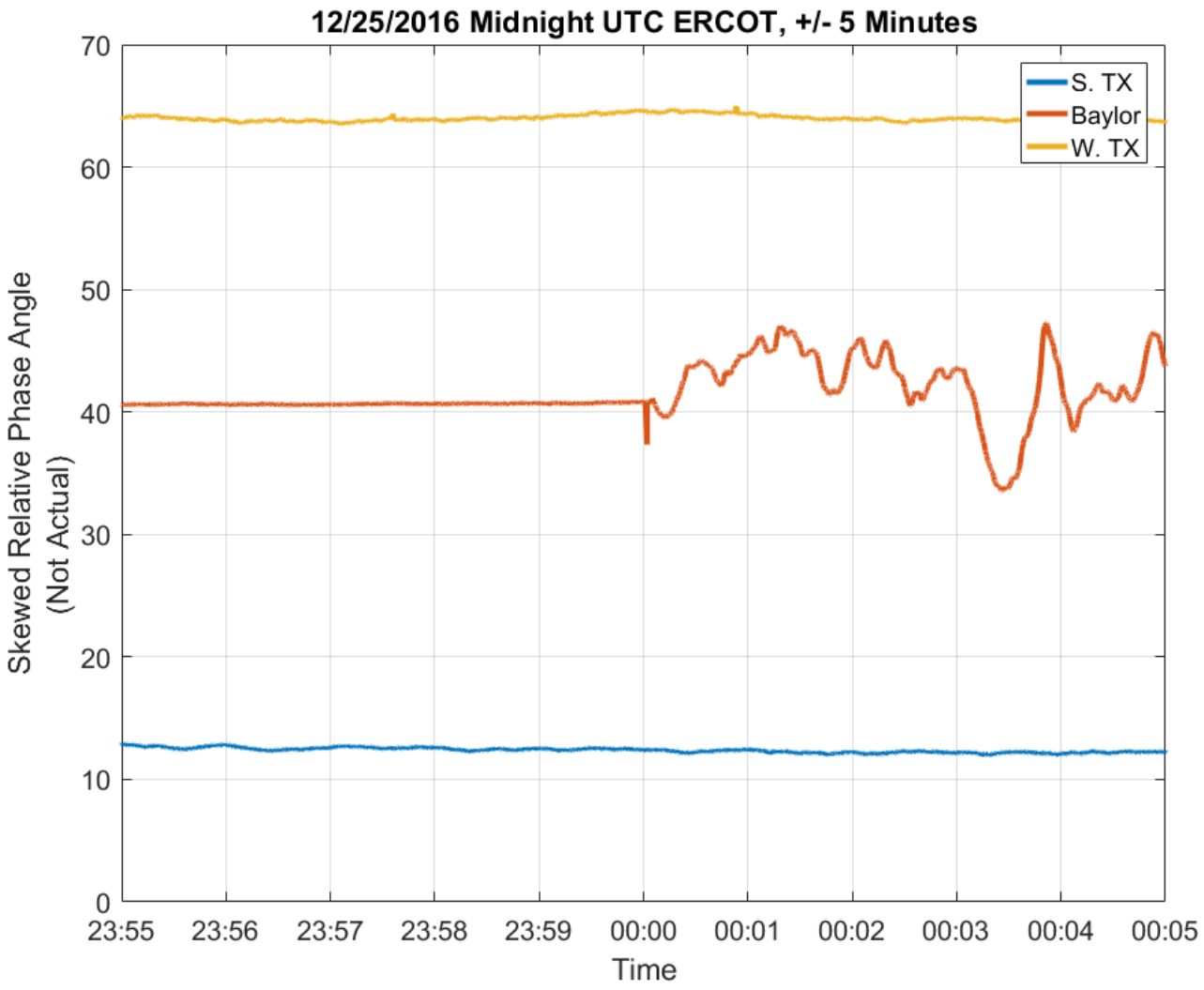
Christmas Eve Frequency - Enhance



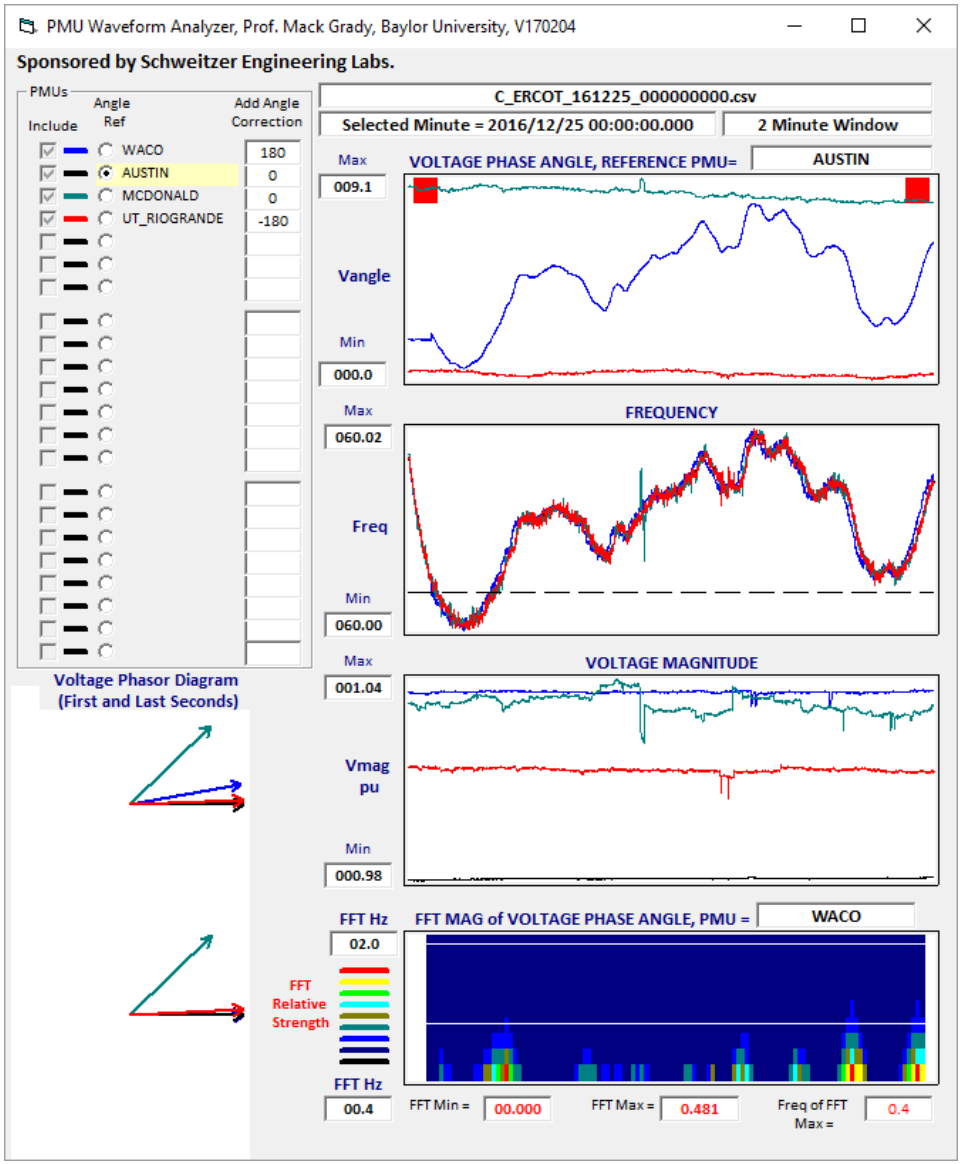
Christmas Eve Frequency - Enhance



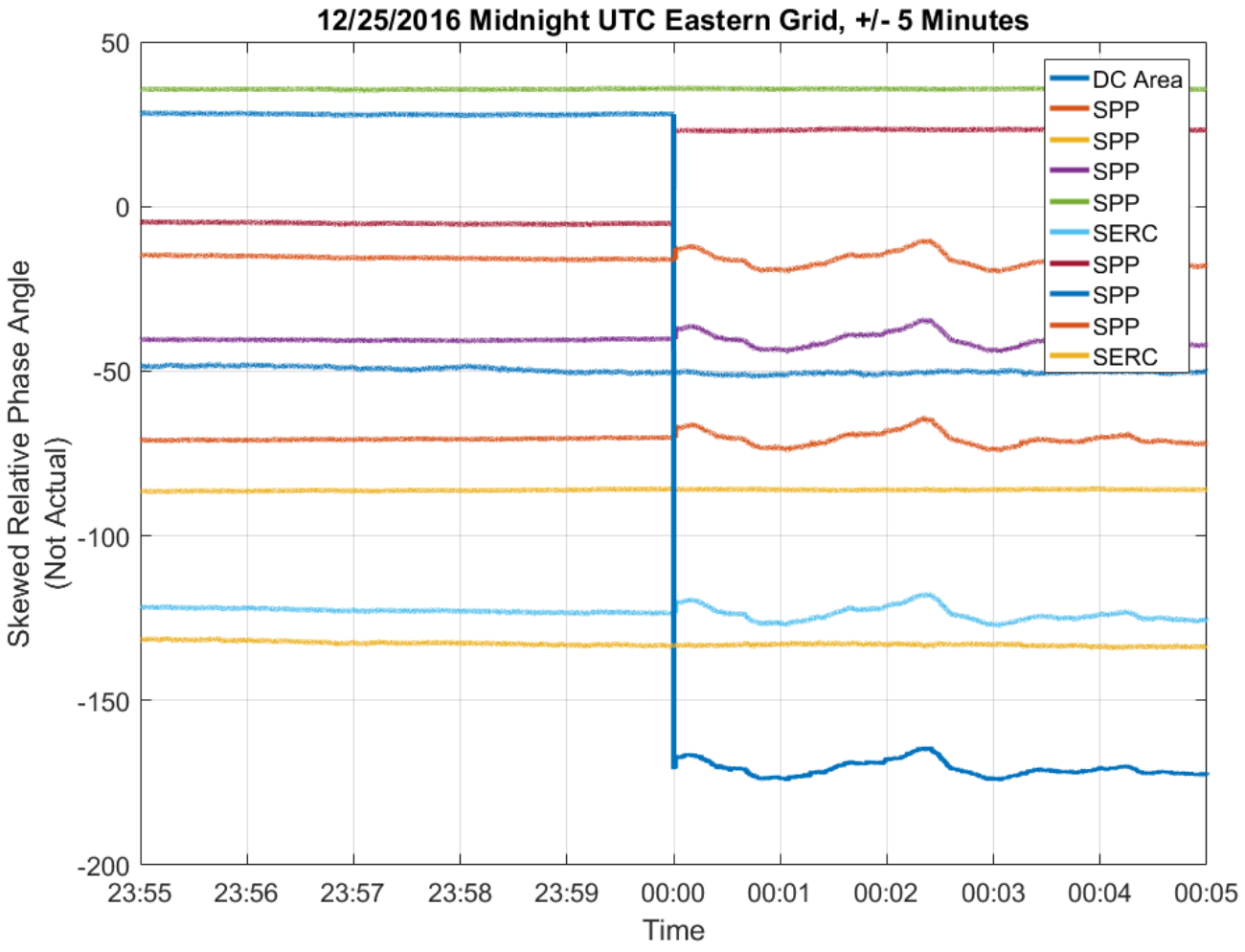
Christmas Eve Phase Angle - ERCOT



Christmas Eve



Christmas Eve Phase Angle – Eastern Grid

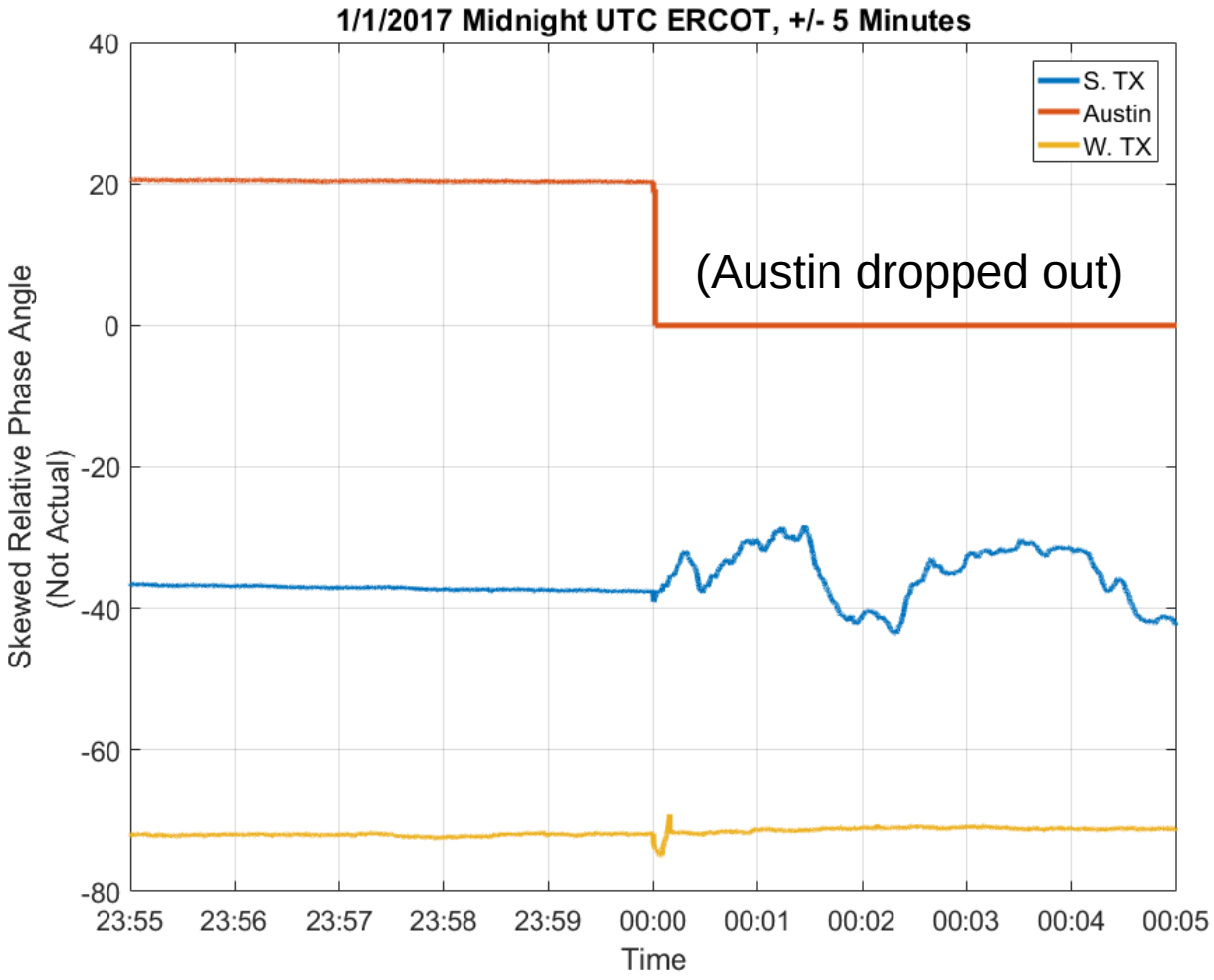


What happened?

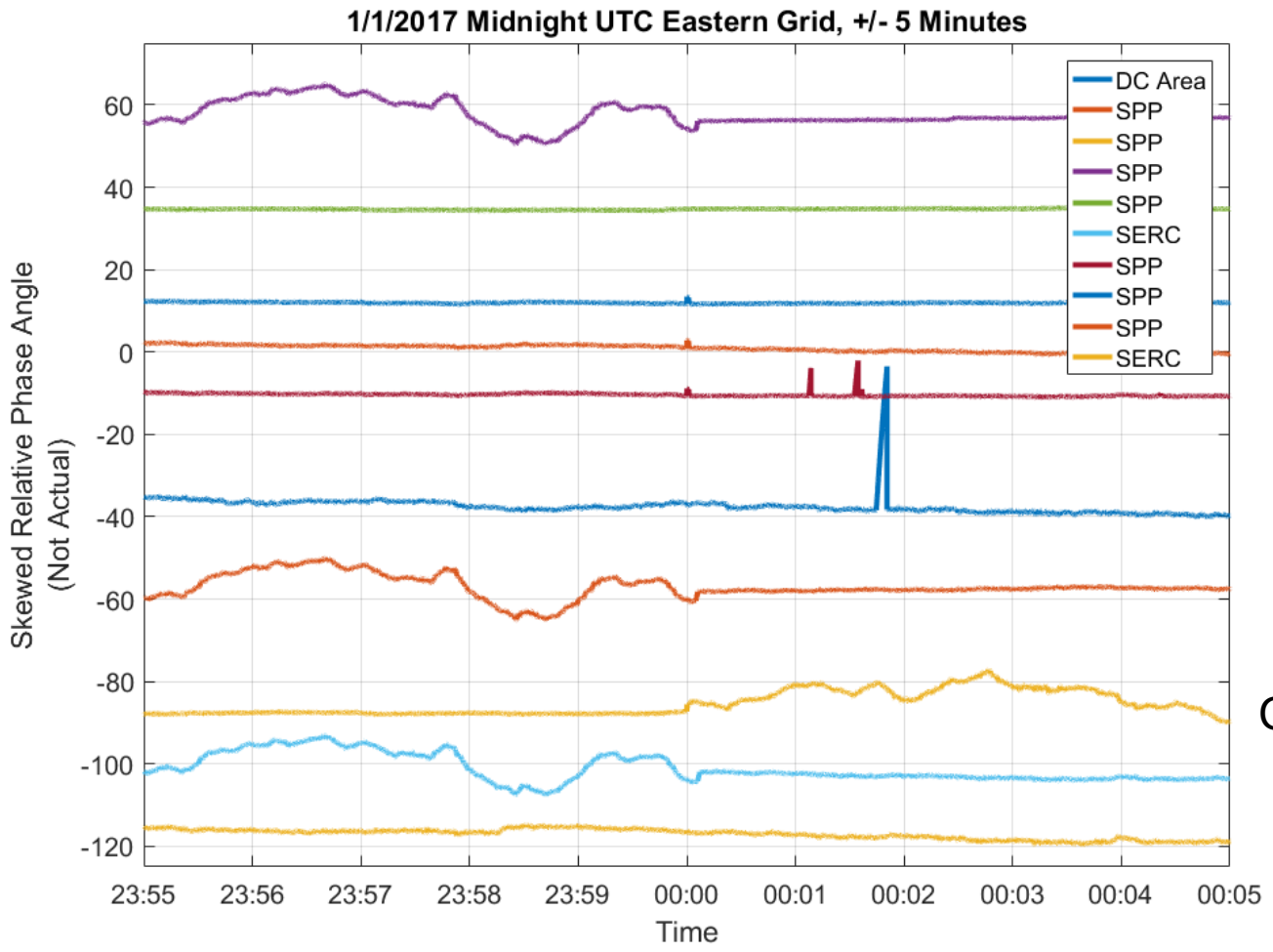
Bit by unpatched firmware. Notification went out in 2013, but we (and others) failed to patch.

The bug: GPS clock will leap one week early based on a pending leap second notification.

NYE Phase Angle – ERCOT



NYE Phase Angle – Eastern Grid



Oops.

Conclusions

- Leap seconds can cause unpredictable behavior on PMU data, such as data drops and phase angle jumps.
- For sites that leap early, or sites that do not leap, phase angle measurements will vary wildly, and frequency measurements will not align.
- Potentially a problem if operations or controls use phase angle measurements for decisions.
- Keep up with your patches – even with your clock that seems to be working fine!

Questions / Comments?

References:

[1] Behrendt, K. and Fodero, K. *The Perfect Time: An Examination of Time-Synchronization Techniques*. From SEL Web Site (Technical Paper).

[2] Allan, D., Ashby, N. and Hodge, C. *The Science of Timekeeping*. Application Note 1289. From Agilent Web Site (App Note).

[3]MrReid.org, *What's the Time?*

http://wordpress.mrreid.org/2011/05/25/whats-the-time/