Use of IEEE 1588–2008 for a Sampled Value Process Bus in Transmission Substations

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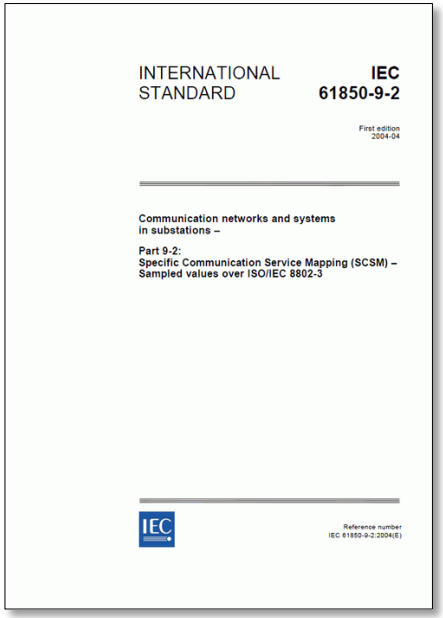

INTERNATIONAL STANDARD

IEC 61850-9-2

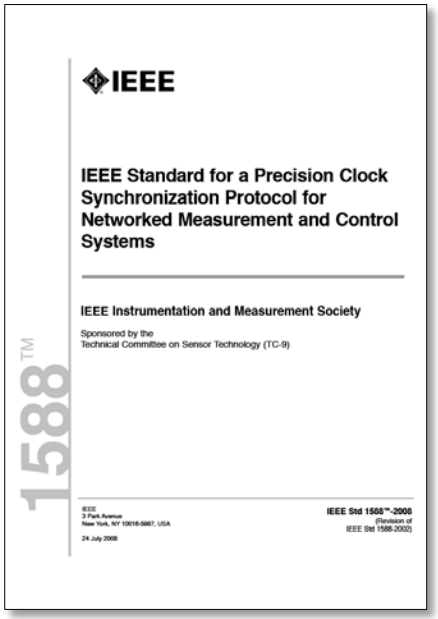
First edition 2004-04

Communication networks and systems in substations –

Part 9-2: Specific Communication Service Mapping (SCSM) – Sampled values over ISO/IEC 8802-3

IEC

Reference number IEC 61850-9-2:2004(E)


IEEE

IEEE Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems

IEEE Instrumentation and Measurement Society

Sponsored by the Technical Committee on Sensor Technology (TC-9)

1588™

IEEE Std 1588™-2008 (Revision of IEEE Std 1588-2002)

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Presentation Overview

- Transmission substations
- Substation automation systems & IEC 61850
- Process Bus timing requirements
- IEEE Std 1588 testing method
- IEEE Std 1588 performance results
- Recommendations

Transmission Substations

The “Transmission Smart Grid”

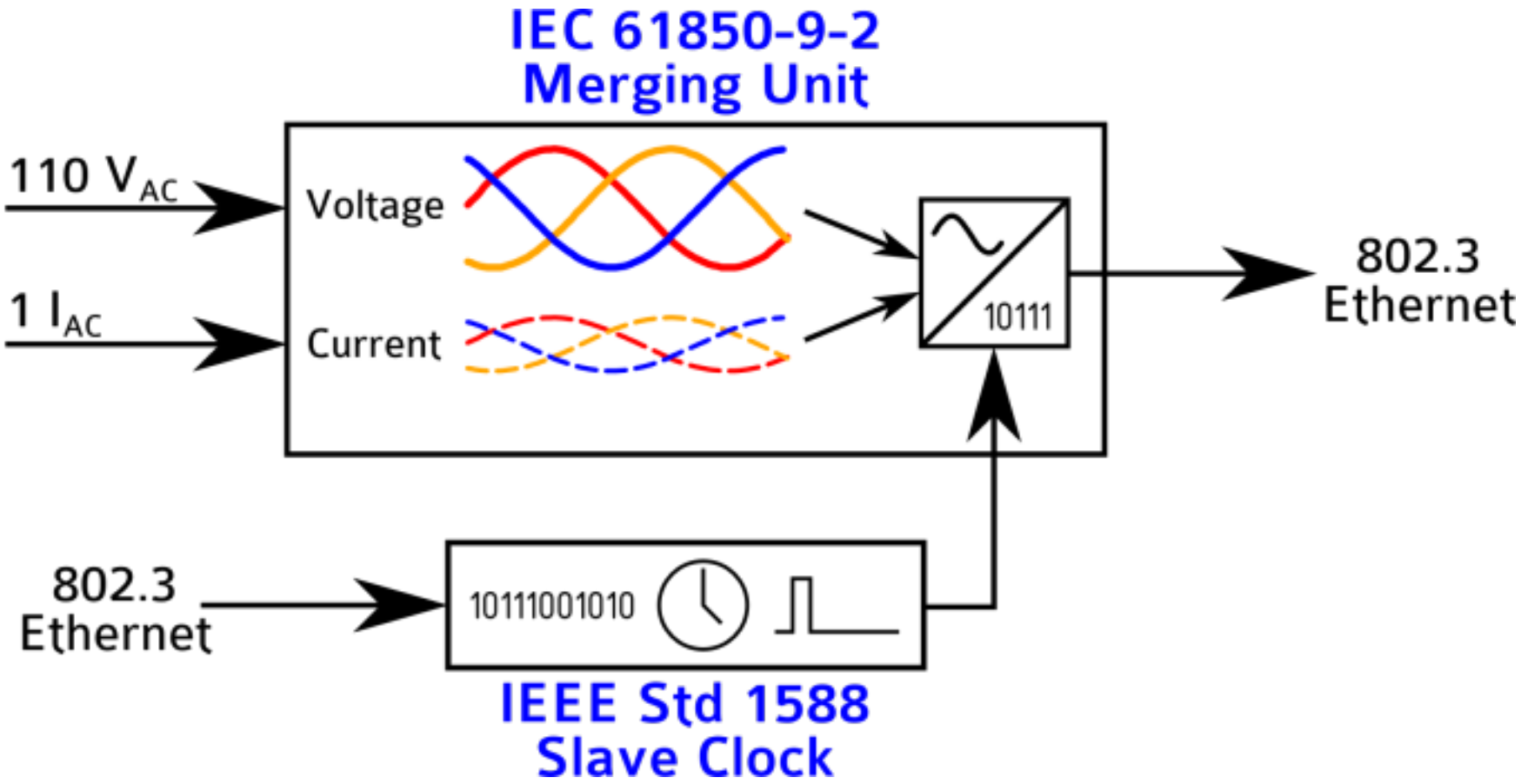
- IEC and NIST have released Smart Grid ‘roadmaps’.
  - ‘Foundation’ standards are recommended.
  - Cooperation between the organisations.

- Characteristics
  - Digitisation
  - Autonomy
  - Coordination
  - Self healing
- Benefits
  - Reliability
  - Flexibility
  - New Technology

Process Bus Definition

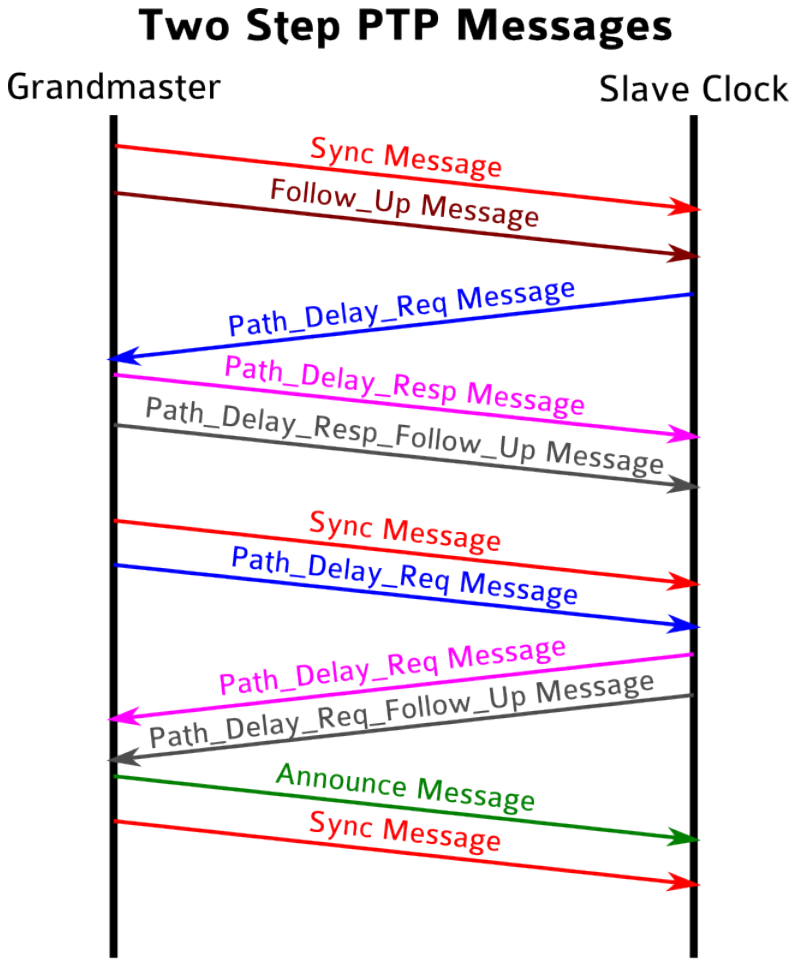
- The process bus carries information from Primary Plant to the SAS, and from the SAS to the primary plant.
- Requires time synchronisation.
- The “merging unit” digitises voltage, current and digital inputs and creates data stream.

Merging Unit Sampling



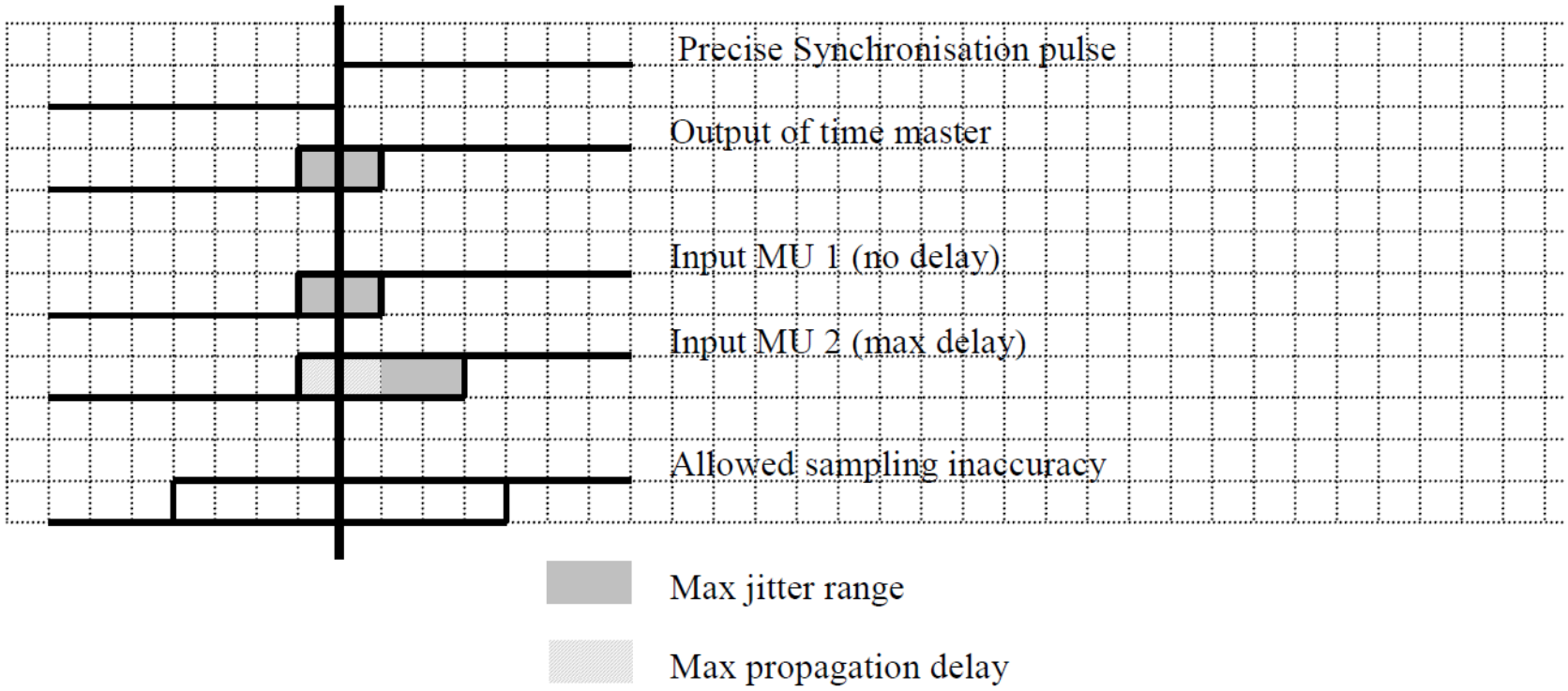
IEEE Std 1588–2008 / PTPv2

- **Grandmaster** provides reference.
- **Slave clock** uses time info, e.g. to create 1PPS signal.
- Ethernet based timing standard.
- Time recovery through message passing.

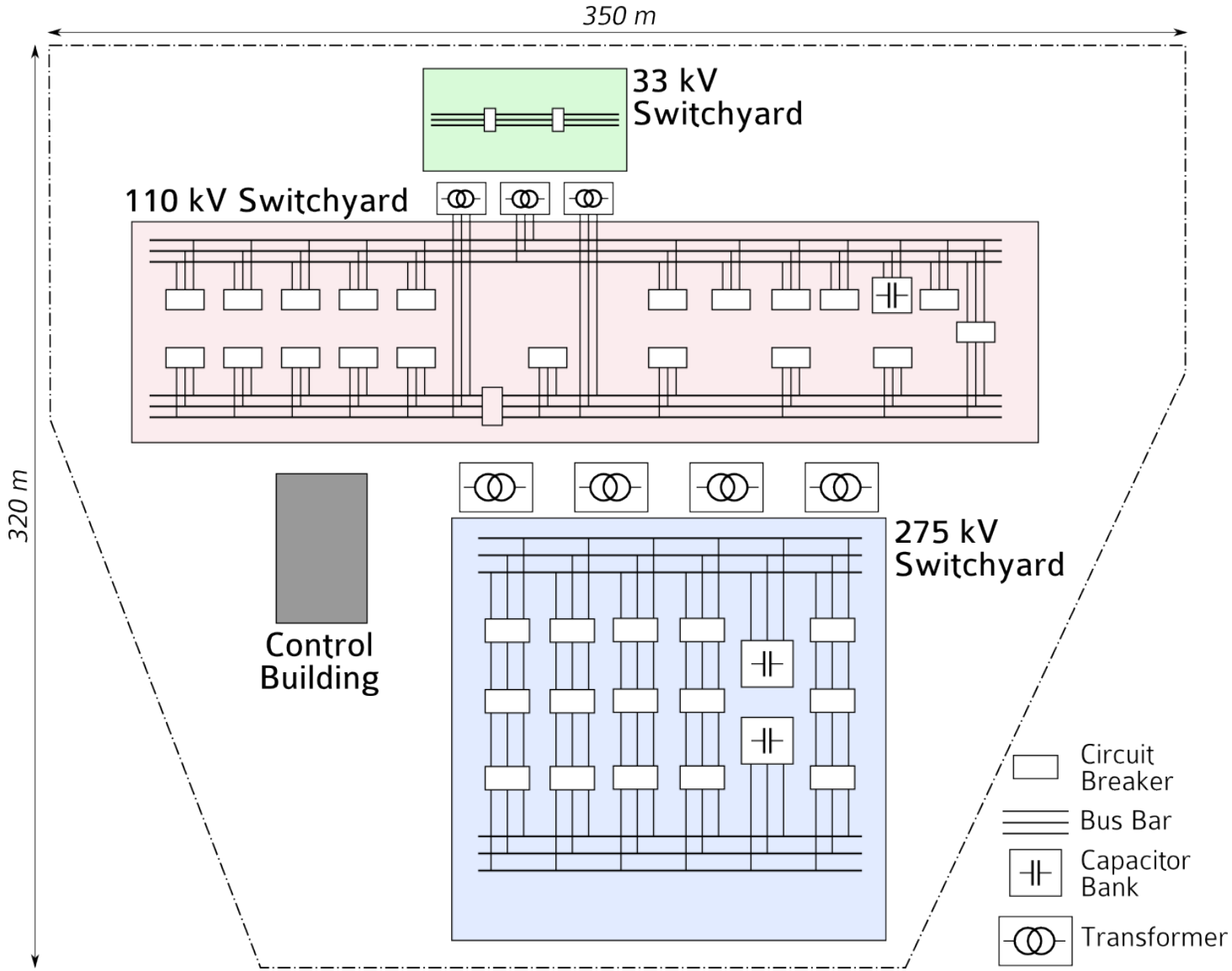


Performance Requirement for Timing

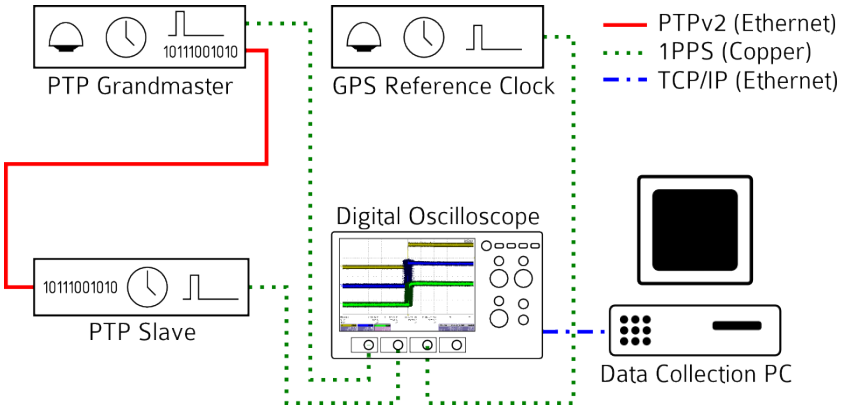
- ±1 µs for sync pulse to achieve overall IEC 61850-5 class T4 (±4 µs)

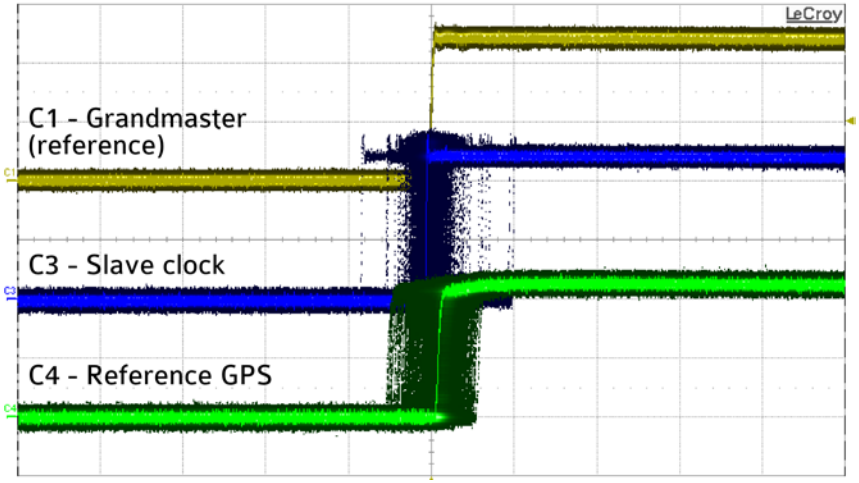


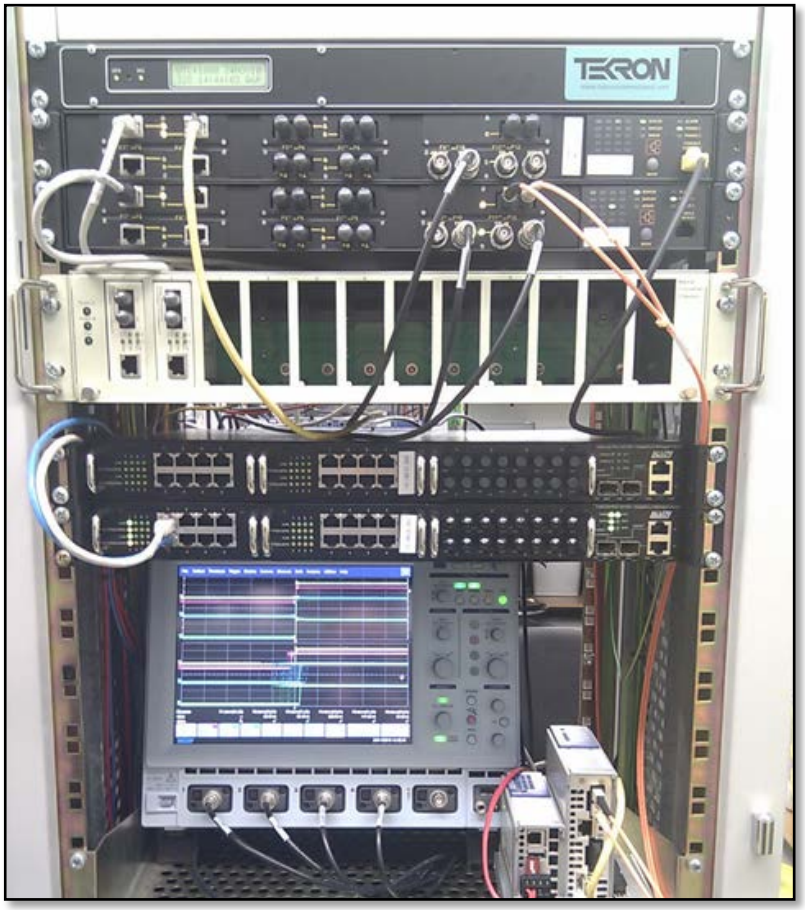
Queensland Substation Layout



Test Equipment





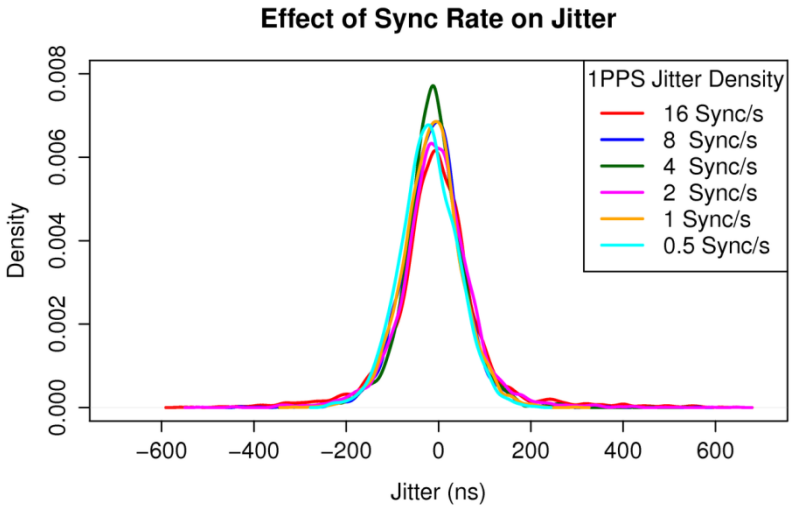


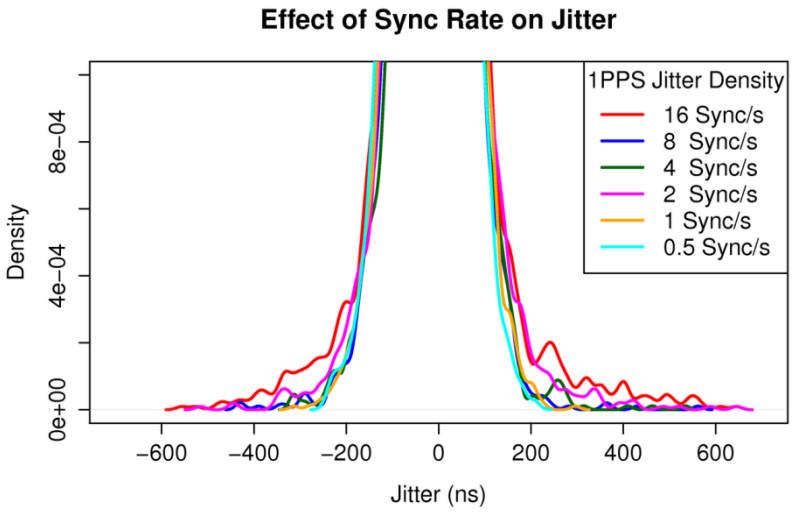
Tests

- Steady state performance
  - Directly connected
  - Using transparent clocks
- Power on performance
- Loss of grandmaster/slave communications
- Loss of grandmaster external synchronisation

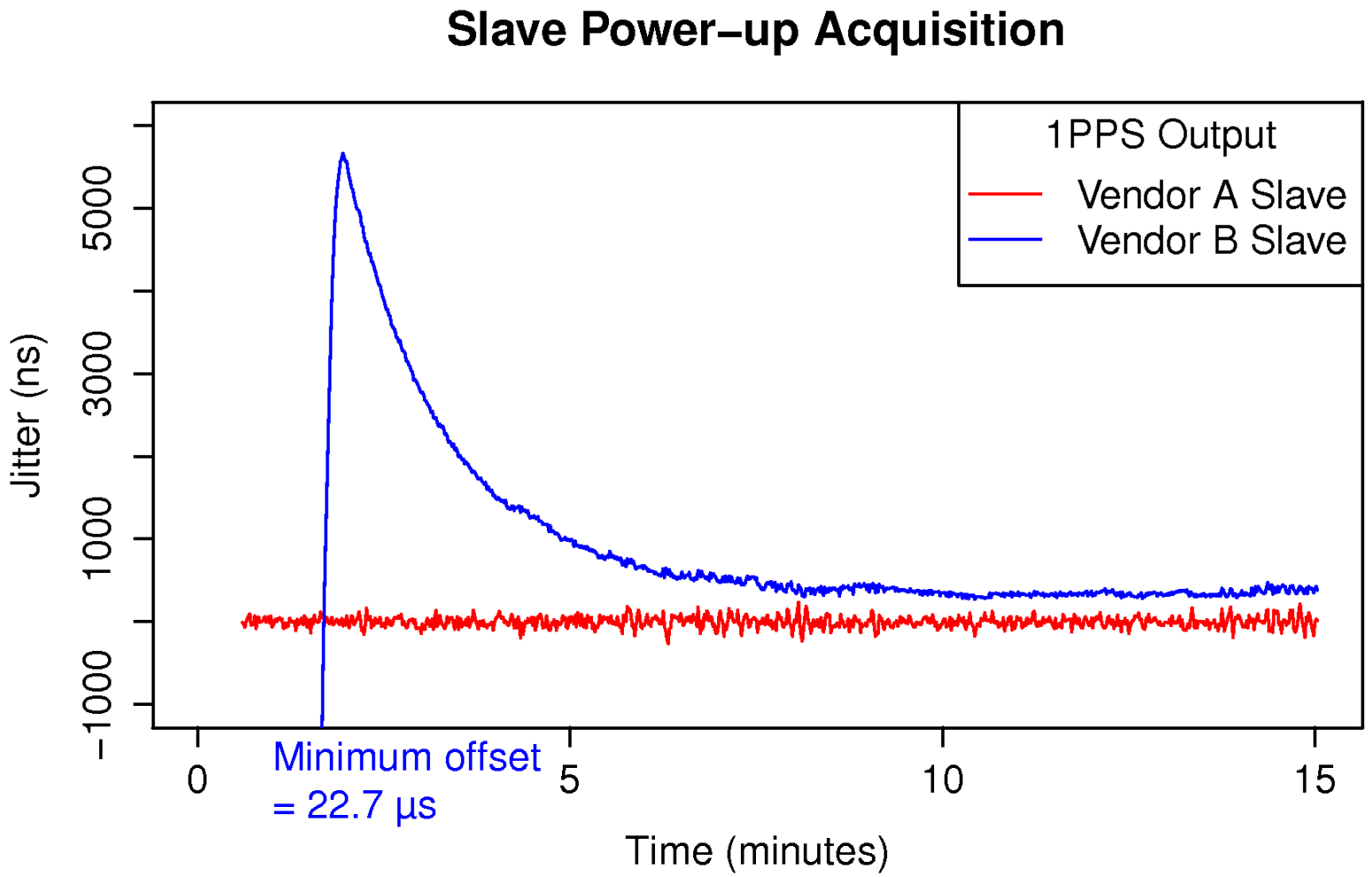
Steady State Performance

- PTP parameters affect performance.
- IEEE Std PC37.238 Power Profile used.
- Peer-peer delay requests and announce messages fixed.
- Sync rate varied.

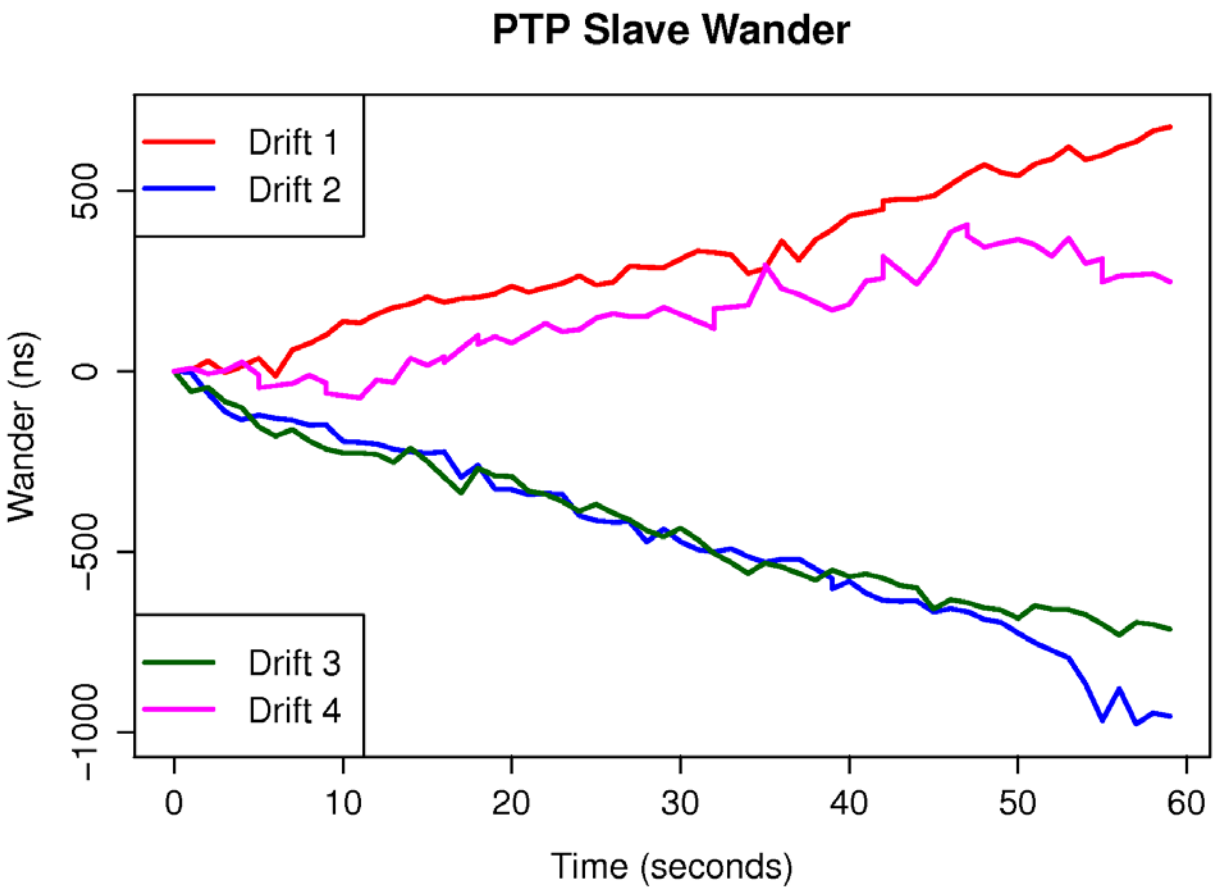


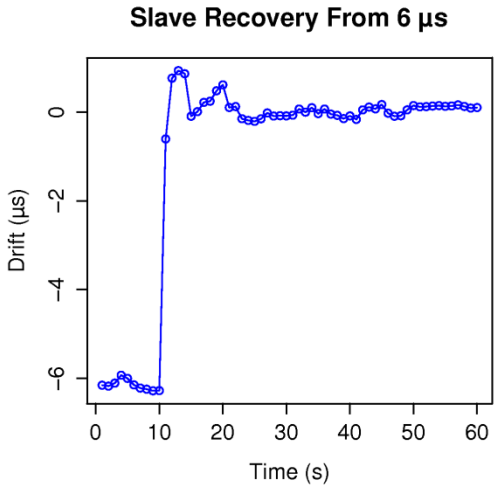


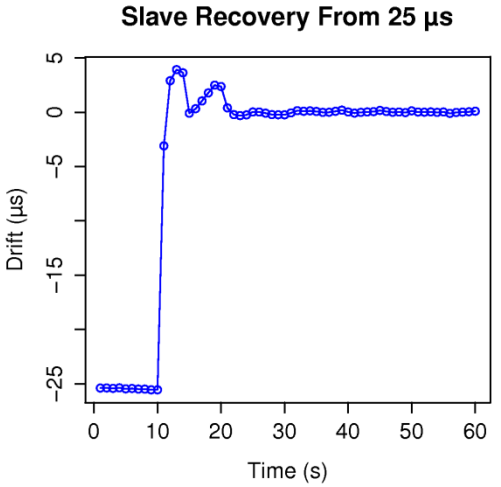
‘Power On’ Performance



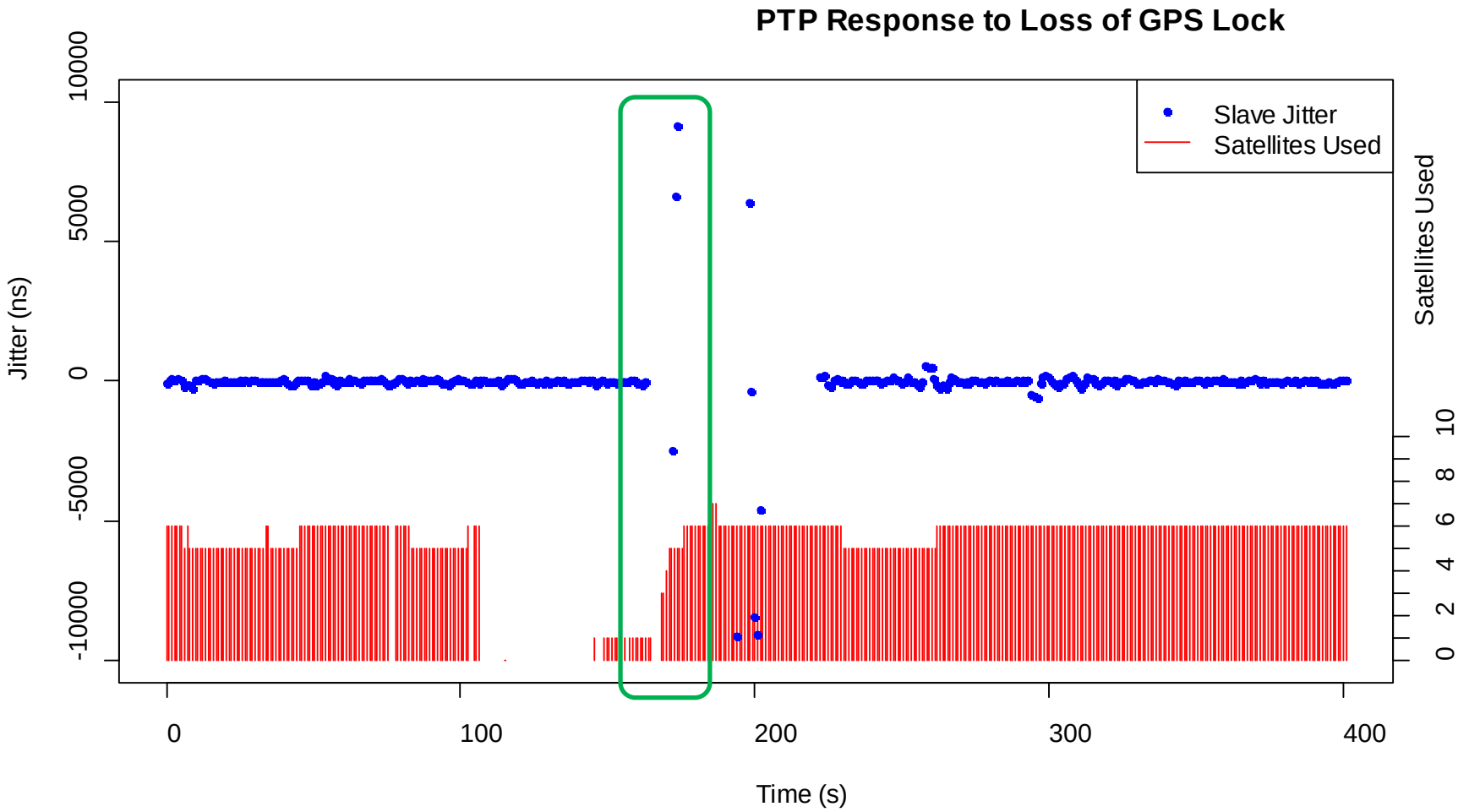
Loss of Grandmaster/Slave Comms



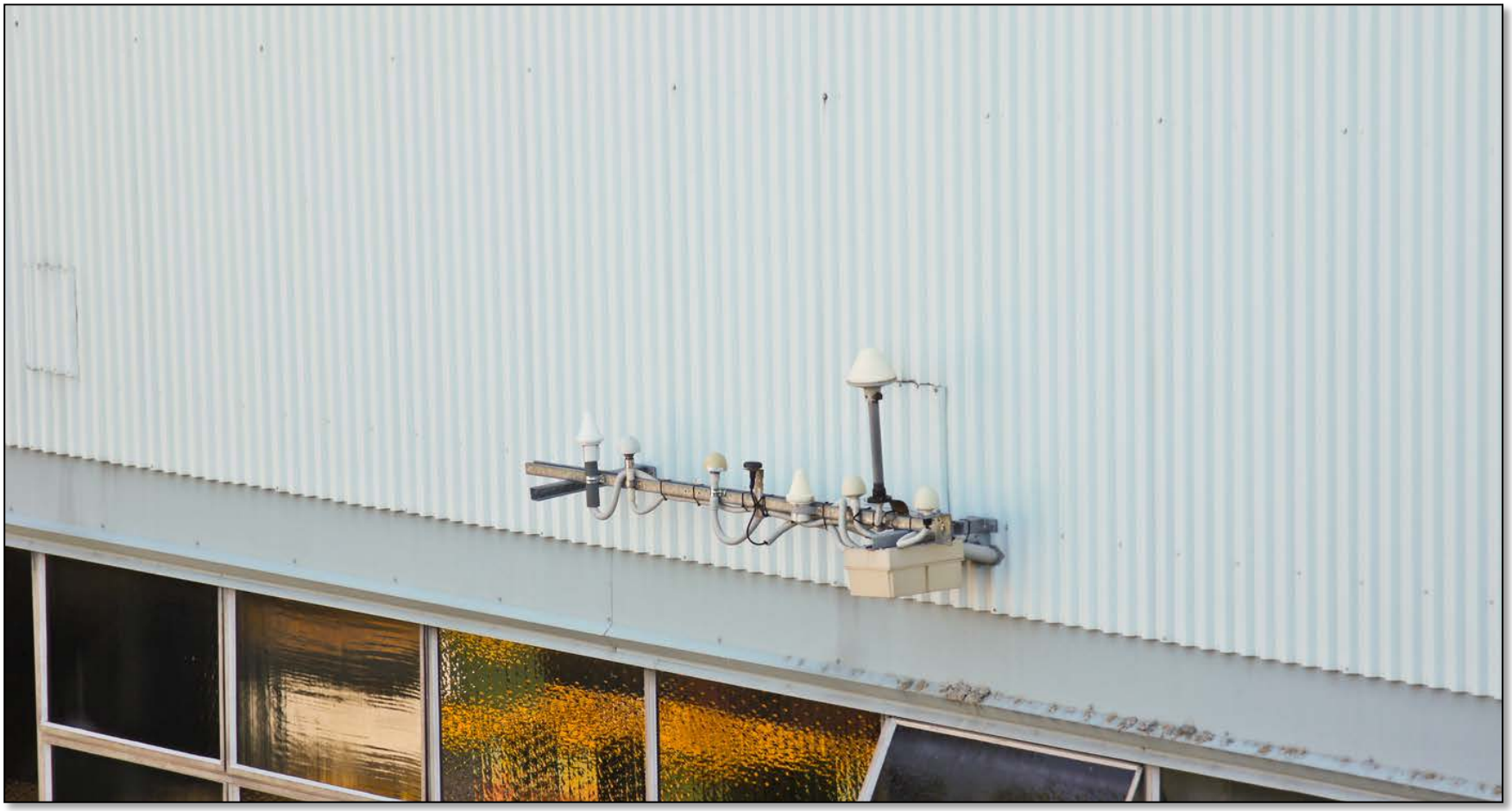




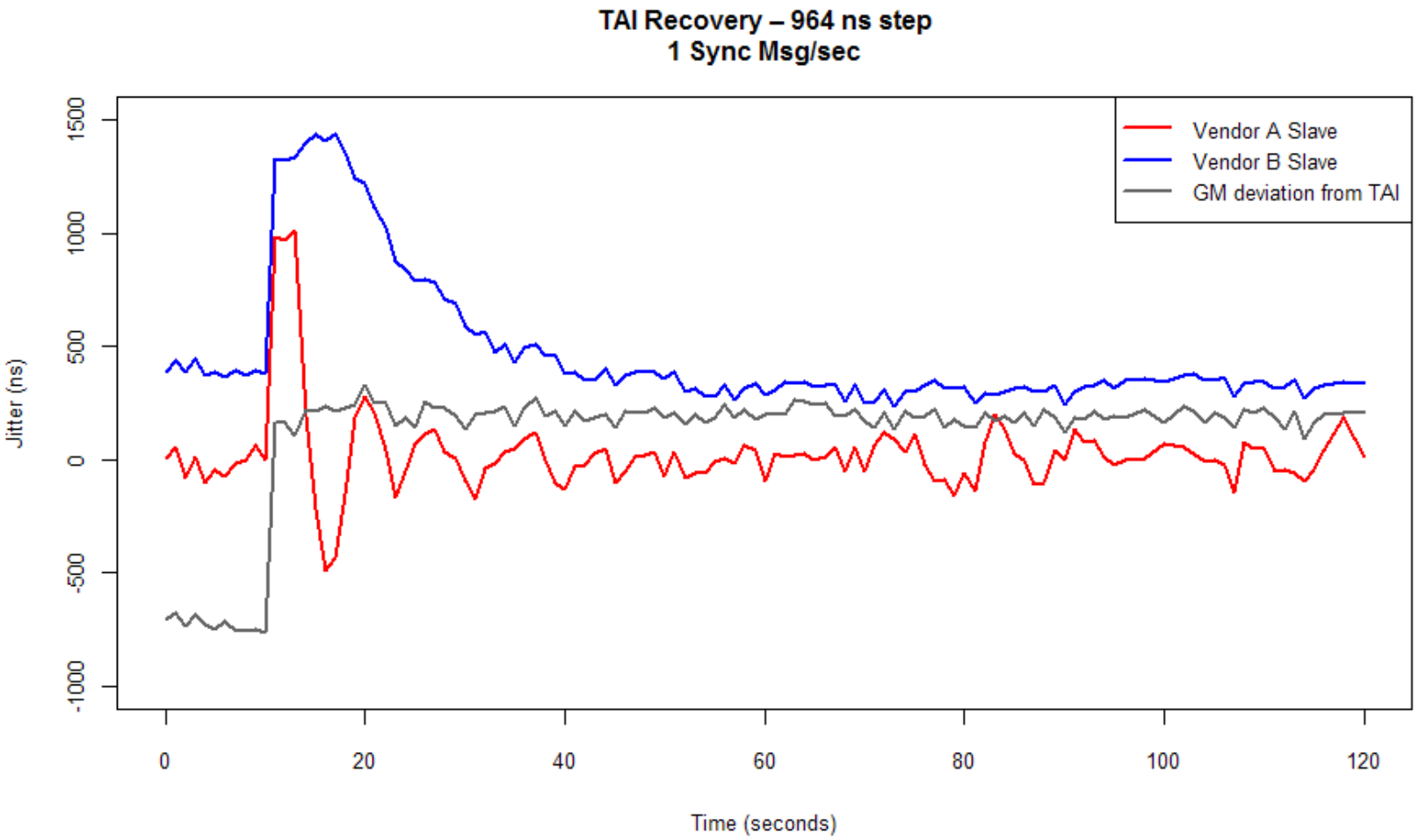
Loss of Grandmaster Discipline Source



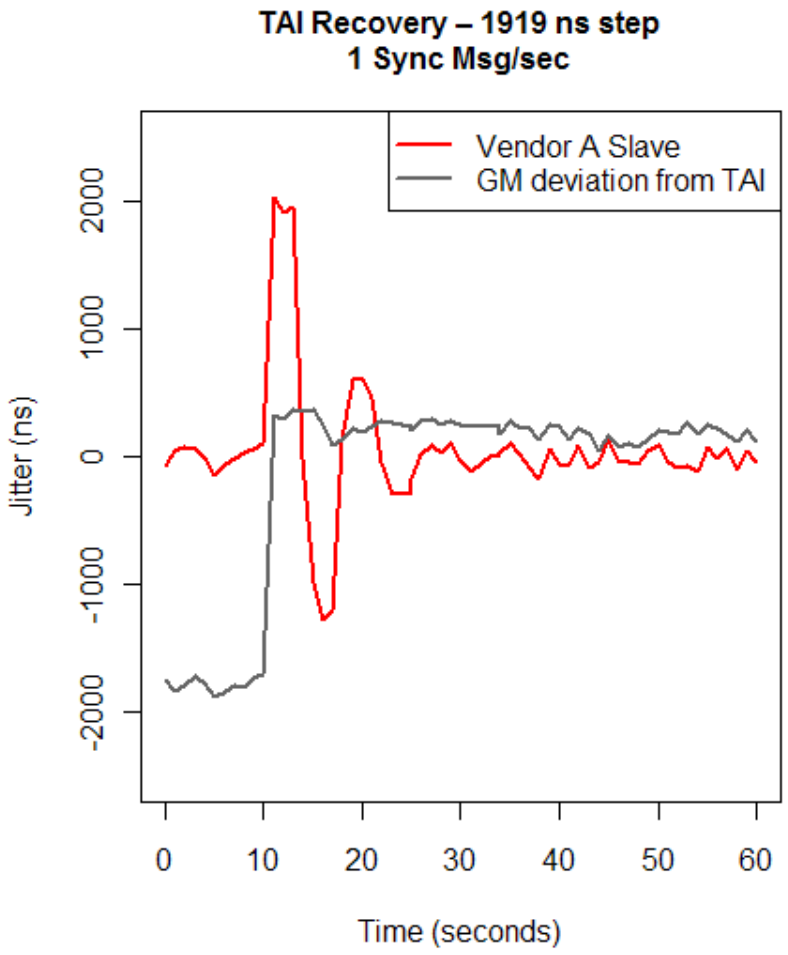
Poor GPS Antenna Placement

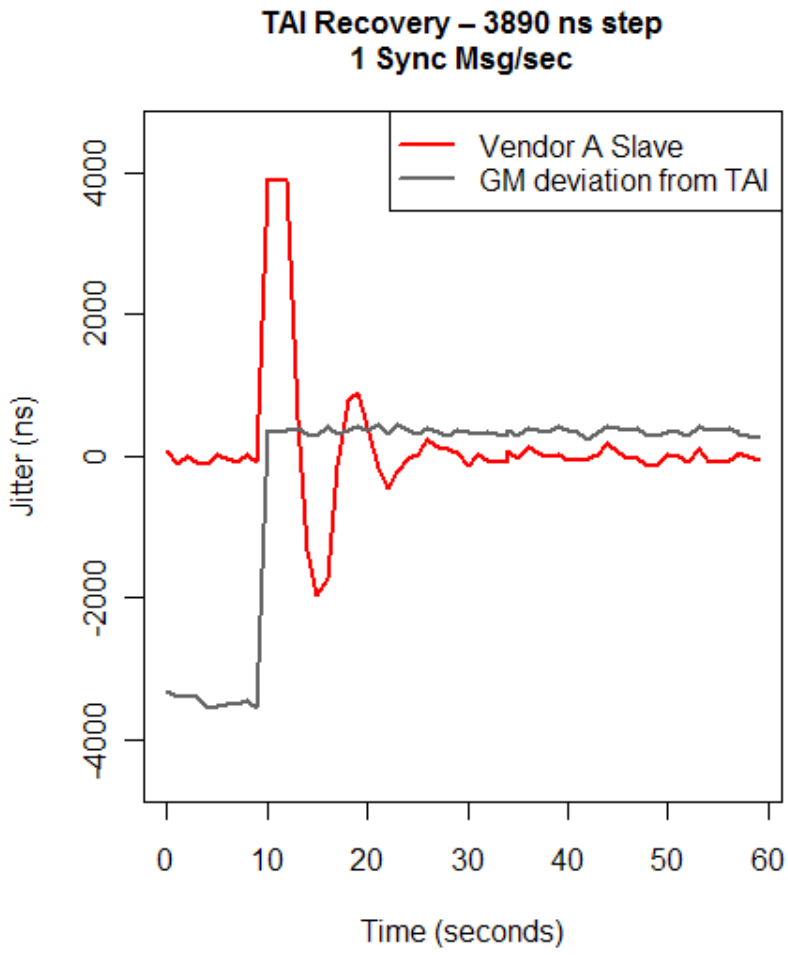


Recreate Loss of GPS Fault



Larger Error Recovery





Proposed Remedy

- Two alternatives:
  - Slower slew rate for slaves
  - Reduced wander in grandmaster.
- Slow slew rate:
  - Leads to errors between sites
  - Difficult to get consistency between vendors
- Reduced wander:
  - More expensive grandmaster required.
  - Improved performance overall

Grandmaster Oscillators

- Invest in the best grandmaster available.
- Reduced phase noise will reduce system jitter too.
- Invest in grandmaster rather than slaves.

Oscillator Type	Stability
Crystal Oscillator (XO)	10^{-4} to 10^{-5}
Temperature Compensated Crystal Oscillator (TCXO)	10^{-6}
Oven Controlled Crystal Oscillator (OCXO)	10^{-8} to 10^{-10}
Rubidium Atomic Frequency Standard (Rb)	10^{-10} to 10^{-11}

Information from Bloch *et. al*, "Mass-Produced Quartz Oscillators as Low-Cost Replacement of Passive Rubidium Vapor Frequency Standards", *2007 IEEE International Frequency Control Symposium Jointly with the 21st European Frequency and Time Forum*, Geneva, Switzerland.

Conclusions

- PTPv2 meets timing requirements for process bus applications.
- Low cost clocks give jitter under ±300 ns.
- Wander of grandmaster needs to be minimised.
- Transient response of slaves to corrections is a concern, and needs to be allowed for.
- IEEE Std 1588 and the IEC 61850 series facilitate the implementation of the transmission smart grid.