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Enhanced PRTC G.8272.1
A New Source for High Precision Time

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WSTS 2017

Outline

- Background and history
  - What/Why ePRTC
  - History: PRC to PRTC to ePRTC
- ePRTC G.8271.2
  - PRTC vs. ePRTC
  - Time Error to UTC
  - Stability: MTIE and TDEV
  - Time holdover
  - New 10 MHz interface (G.703)
  - Tightened 1PPS/TOD interface
  - Autonomous primary reference clock
- ePRC G.811.1
  - ePRTC requires autonomous primary reference clock
  - G.8272.1 Annex A => G.811.1

What/Why ePRTC

What is an ePRTC?

- Defined in ITU-T G.8272.1 (consented Sept 2016, published Feb 2017)
- GNSS (time reference) and autonomous primary reference clock as required inputs

Why the ePRTC?

- ePRTC attributes
  - Reliability: Immune from local jamming or outages
  - Autonomy: Atomic clock sustained timescale with & without GNSS connection
  - Coherency: 30ns coordination assures overall PRTC budget
  - Holdover: 14-day time holdover <= 100 ns

History of the Primary Reference Clock

INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

G.811

(11/1988)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Design objectives for digital networks

Timing requirements at the outputs of primary reference clocks suitable for plesichronous operation of international digital links

The ITU misspelled "plesiochronous" in the title!

But spelled it right here.

1 General

1.1 *International connections and network synchronization considerations*

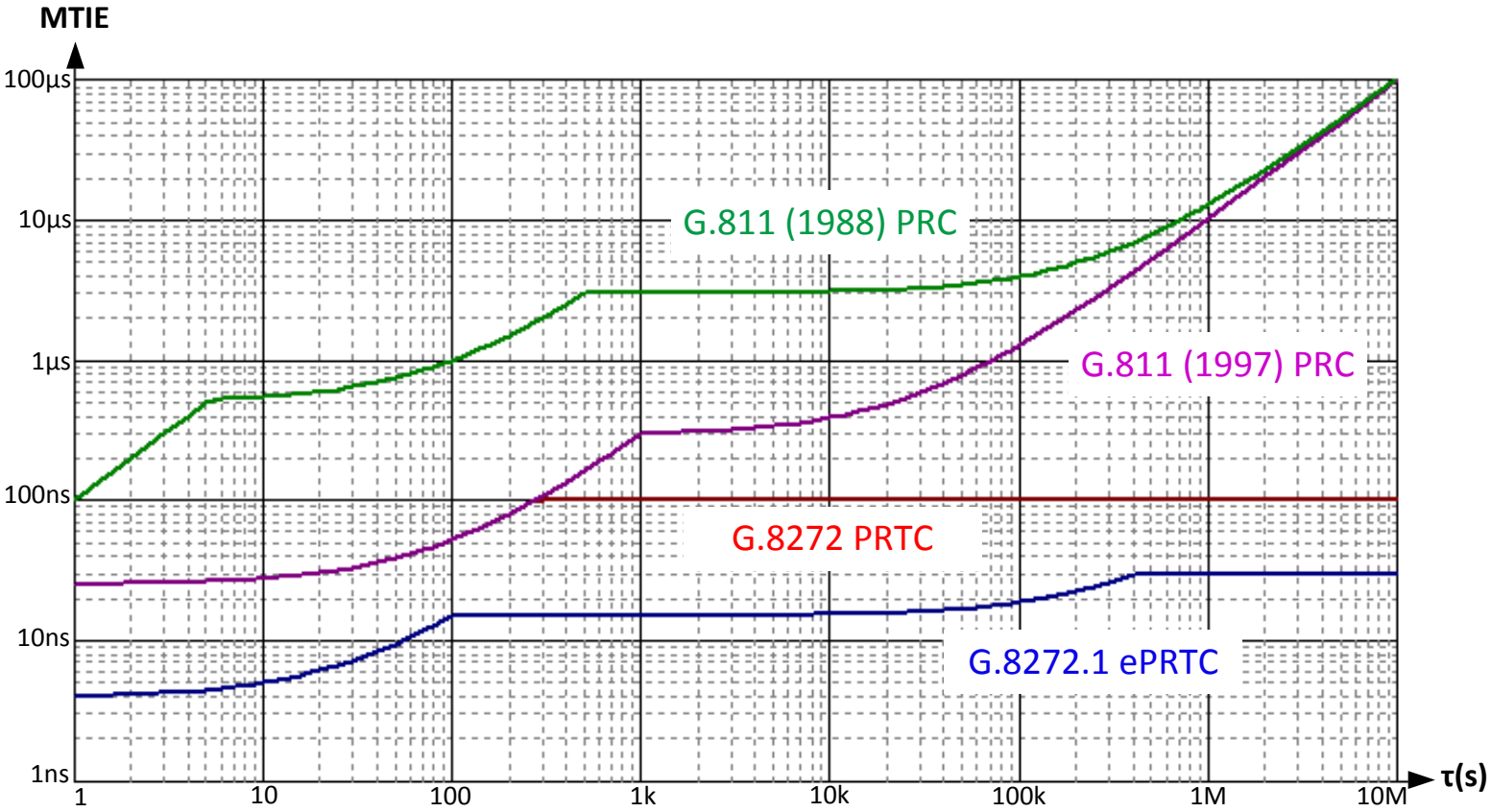
National digital networks, which may have a variety of internal synchronization arrangements, will usually be connected by international links which operate plesiochronously. International switching centres (ISCs) will be interconnected directly or indirectly via one or more intermediate ISCs, as indicated in the hypothetical reference connection (HRX) shown in Figure 1/G.801.

International connections terminate on synchronous network nodes that may or may not be co-located with a primary reference clock. Such network nodes may include slave clocks. Therefore, synchronous network node clock specifications are essential to ensure satisfactory operation of plesiochronous international digital links.

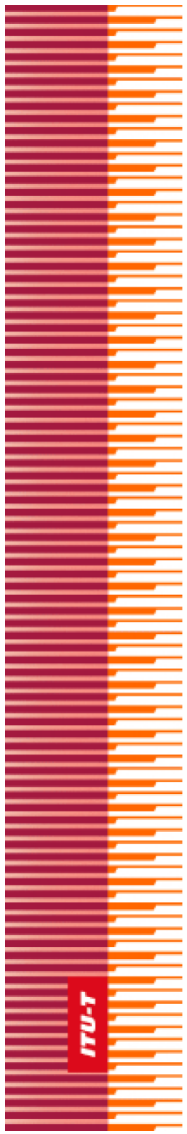
History of the Primary Reference Clock

- G.811 (1988) *Timing requirements at the outputs of primary reference clocks suitable for plesiochronous operation of international digital links*
  MTIE (500s)= 3µs
- G.811 (1997) *Timing characteristics of primary reference clocks*
  MTIE (500s)= 300ns
- G.8272 (2012) *Timing characteristics of primary reference time clocks*
  MTIE (500s)= 100ns
- G.8272.1 (2016) *Timing characteristics of enhanced primary reference time clocks*
  MTIE (500s)= 15ns

History of the Primary Reference Clock



G.8272.1 ePRTC



ITU-T **G.8272.1/Y.1367.1**

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

(11/2016)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Packet over Transport aspects – Synchronization, quality and availability targets

SERIES Y: GLOBAL INFORMATION INFRASTRUCTURE, INTERNET PROTOCOL ASPECTS, NEXT-GENERATION NETWORKS, INTERNET OF THINGS AND SMART CITIES

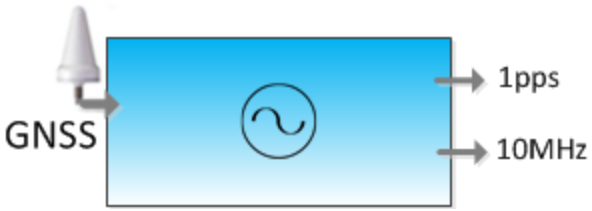
Internet protocol aspects – Transport

Timing characteristics of enhanced primary reference time clocks

Recommendation ITU-T G.8272.1/Y.1367.1

PRTC vs. ePRTC Time Accuracy and Stability

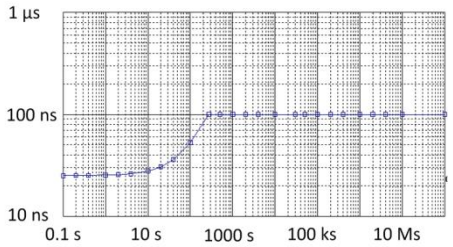
PRTC



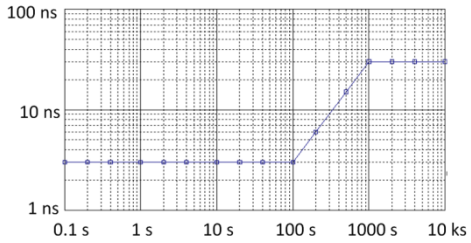
G.8272

Time Accuracy → Time Error: <=100ns

Time Stability → MTIE



Time Stability → TDEV



MTIE is G.811 with 100 ns maximum
TDEV is G.811 exactly

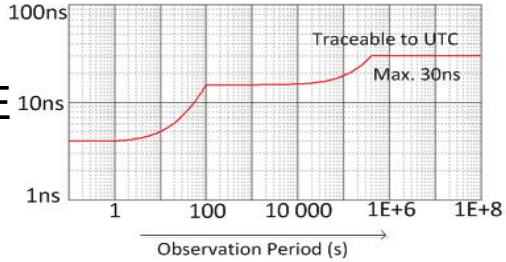
ePRTC

10 MHz from PRC (Cs)

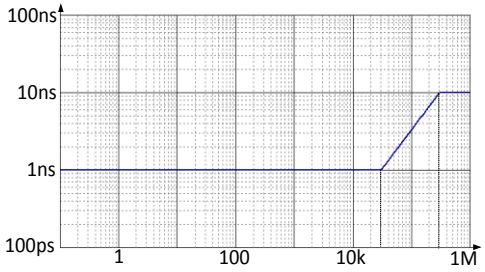
G.8272.1

Time Accuracy → Time Error: <=30ns

Time Stability → MTIE

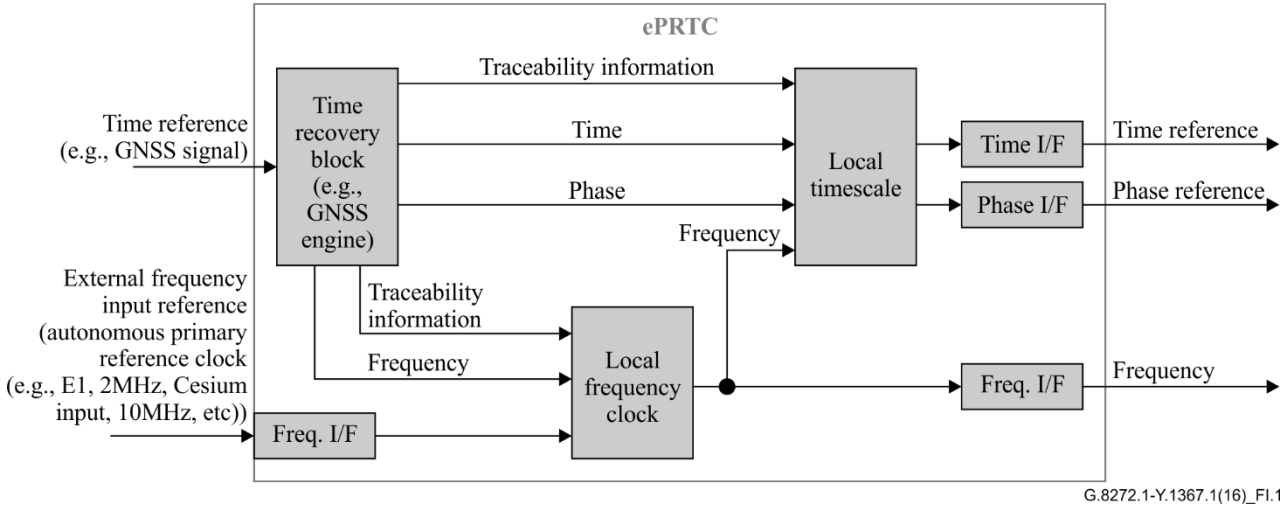


Time Stability → TDEV



MTIE below G.8272 with 30 ns maximum
TDEV below G.8272 and tau extended

ePRTC Functional Model

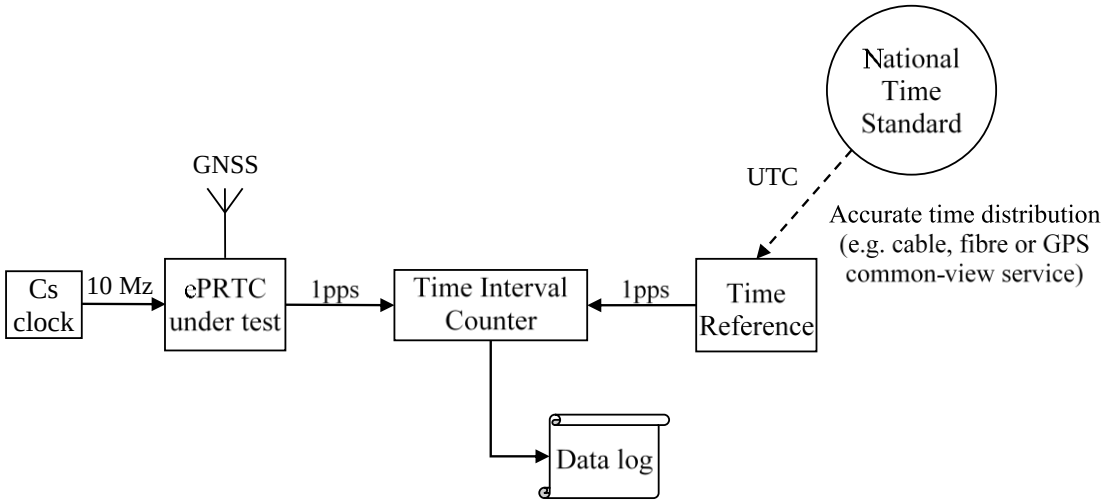


"Autonomous primary reference clock" is a key component of the ePRTC

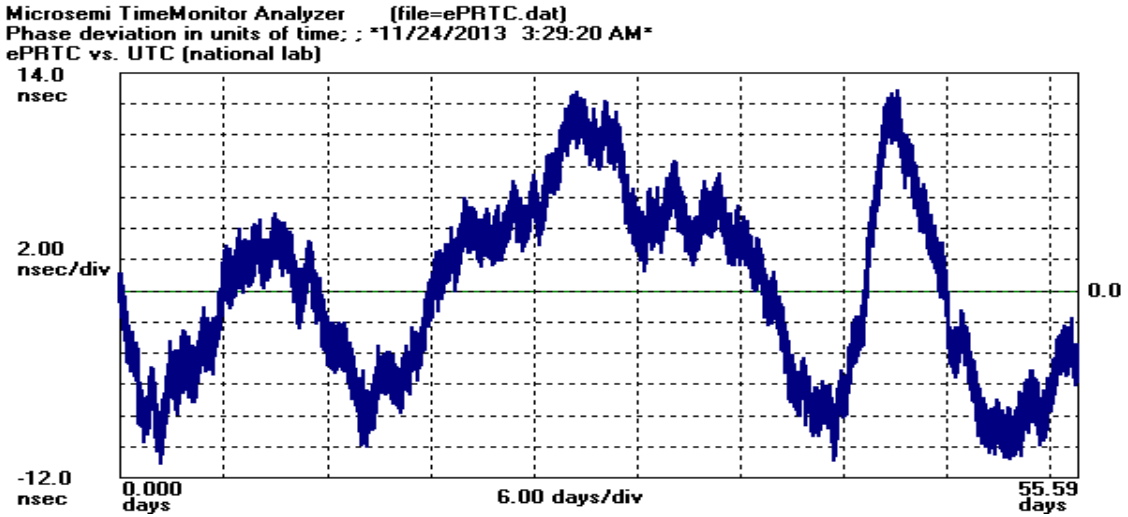
- Provides for highly accurate time of better than 30ns to UTC in combination with time reference
- Provides robust atomic-clock based time even during extended GNSS outages
- Long time constants can address diurnal effects such as those arising from variation in ionospheric delay of signals from GNSS satellites

Time Accuracy: ±30 ns vs. UTC

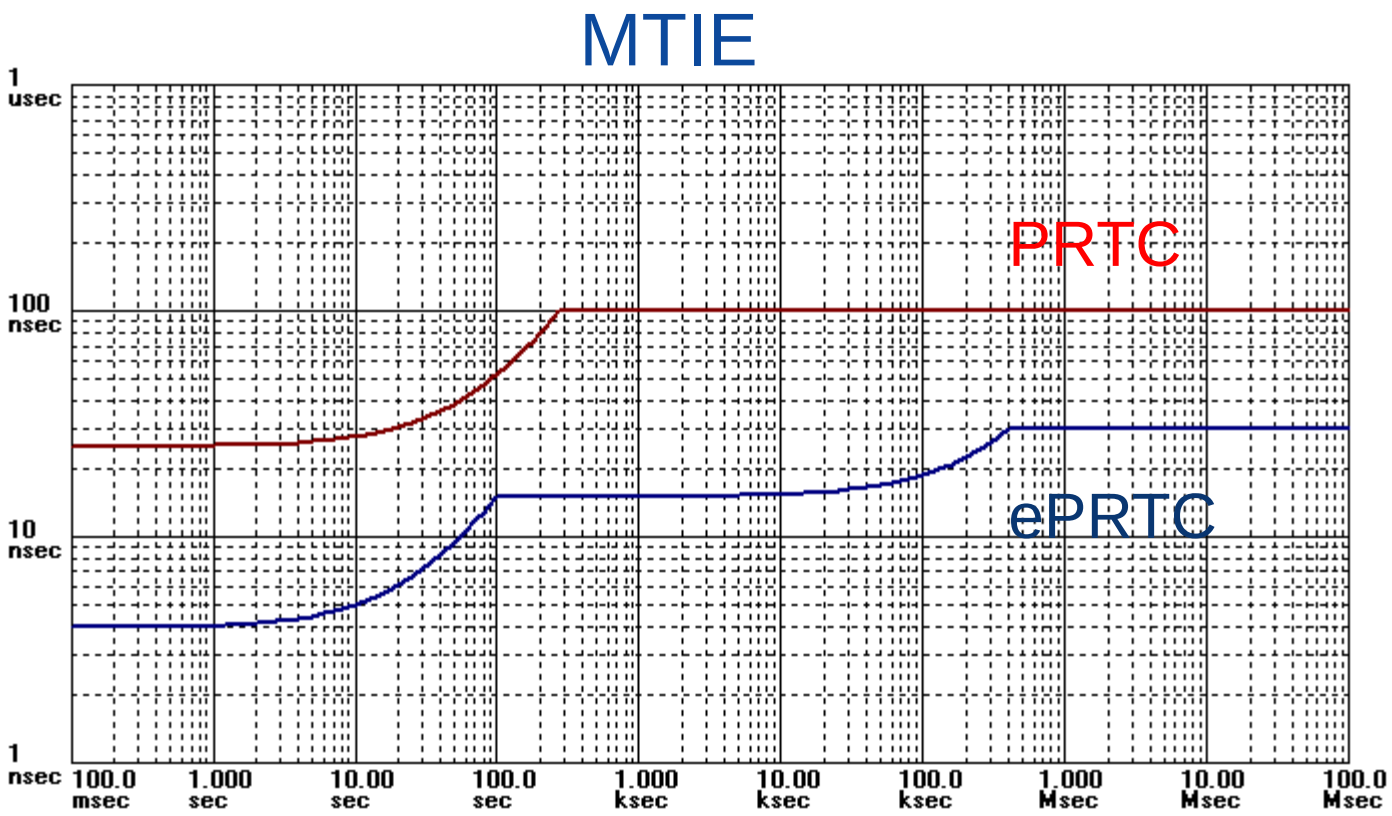
Setup for testing ePRTC against UTC:



Example measurement of ePRTC vs. UTC measured at a national lab:

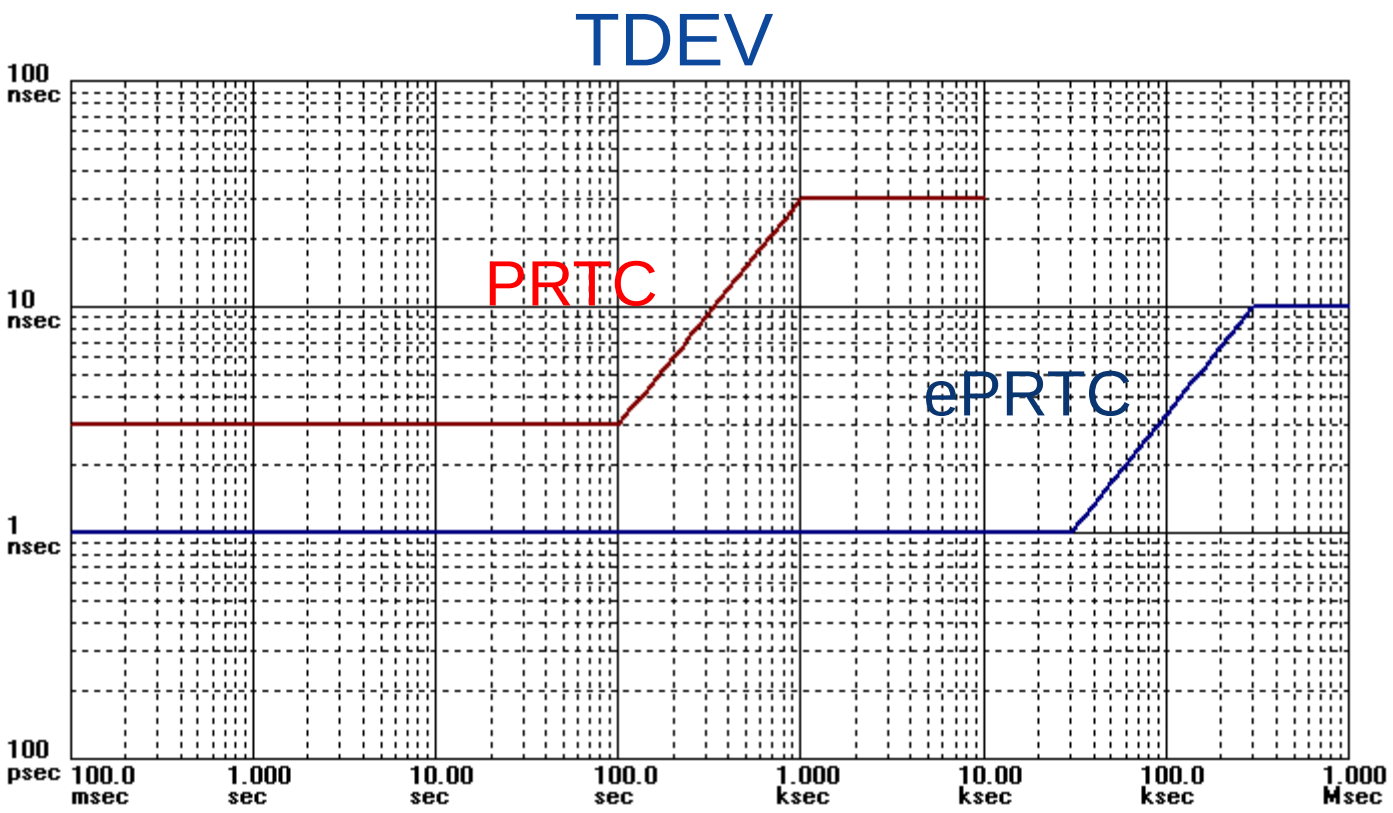


ePRTC stability: MTIE



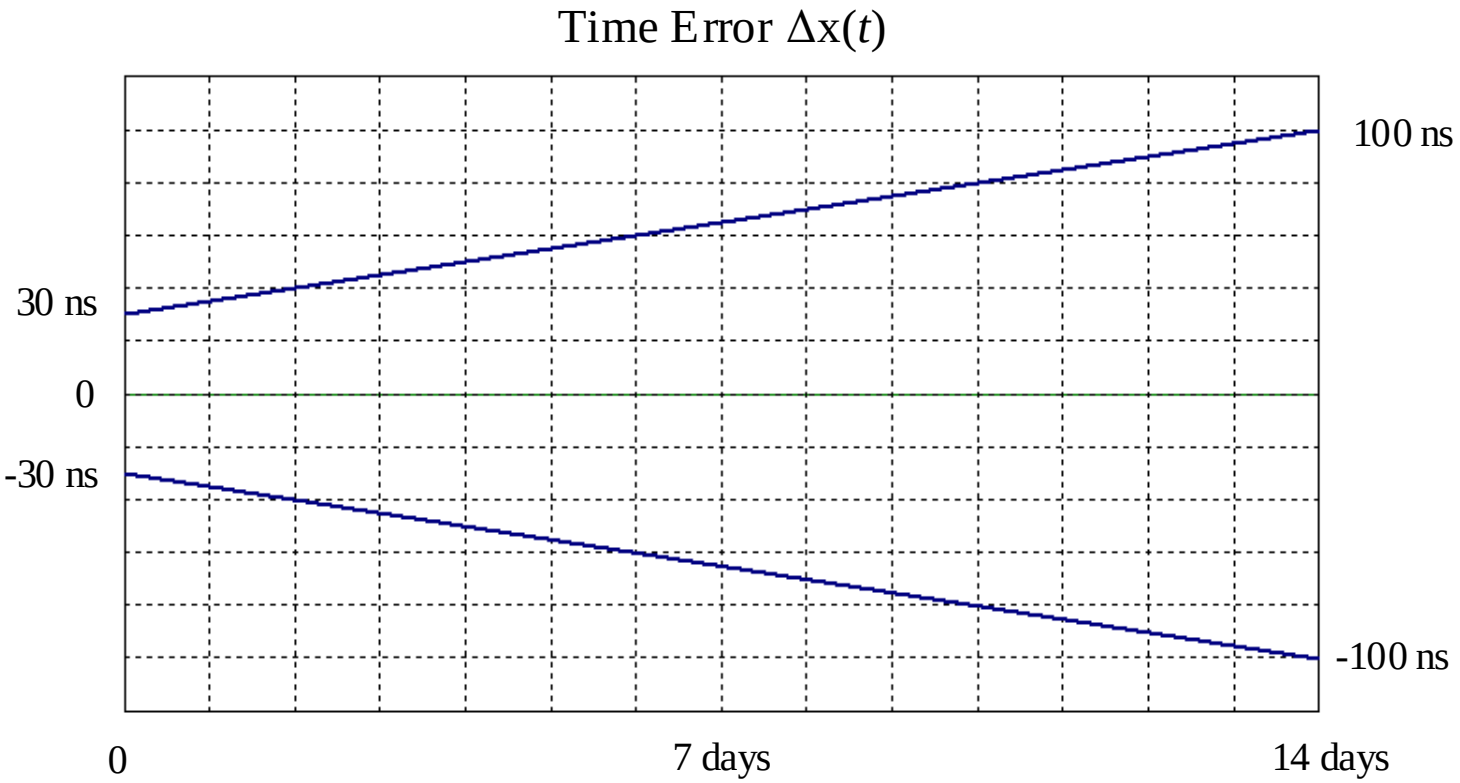
- ePRTC MTIE: 4ns for low tau, 15ns for tau 100s to 10ks, 30ns above 300ks
- ePRTC MTIE: everywhere below PRTC by nearly an order of magnitude

ePRTC stability: TDEV



- ePRTC TDEV: 1ns for tau up to 30 ks, 10ns for tau 300ks to 1Ms
- ePRTC TDEV: everywhere below PRTC TDEV, as much as 30x
- ePRTC TDEV: tau extends to 1 000 000 s (only 10 000 s for PRTC)

ePRTC Time Holdover



- ePRTC: Hold better that 100ns for 14 days of holdover “Class A” (PRTC time holdover not defined)
- ePRTC: Longer holdover under discussion “Class B” (100ns for 80 days under discussion)
- ePRTC: The longer the holdover, the better the “autonomous primary reference” required

New 10 MHz Interface for the ePRTC

G.703

- New 10 MHz interface added to G.703 (04/2016)
- 0V offset, 0.5 to 5V peak-to-peak
- Sine or square wave
- Short, low-loss, low-distortion, cable recommended

G.811

- Jitter less than 1 ns peak-to peak (0.01 UIpp)

G.8272.1

- The 10 MHz input interface should tolerate jitter as defined by [ITU-T G.811] for the 10 MHz output interface
- The jitter tolerance for the other interfaces identified in clause 9 is for further study.

Tightened 1PPS/TOD interface for the ePRTC

V.11

- V.11 defines the balanced interface.

G.8271

- G.8271 Annex A defines details of the V.11-based time/phase interface such as TOD message structure and message details. A 1PPS 50Ω measurement interface is also specified there.

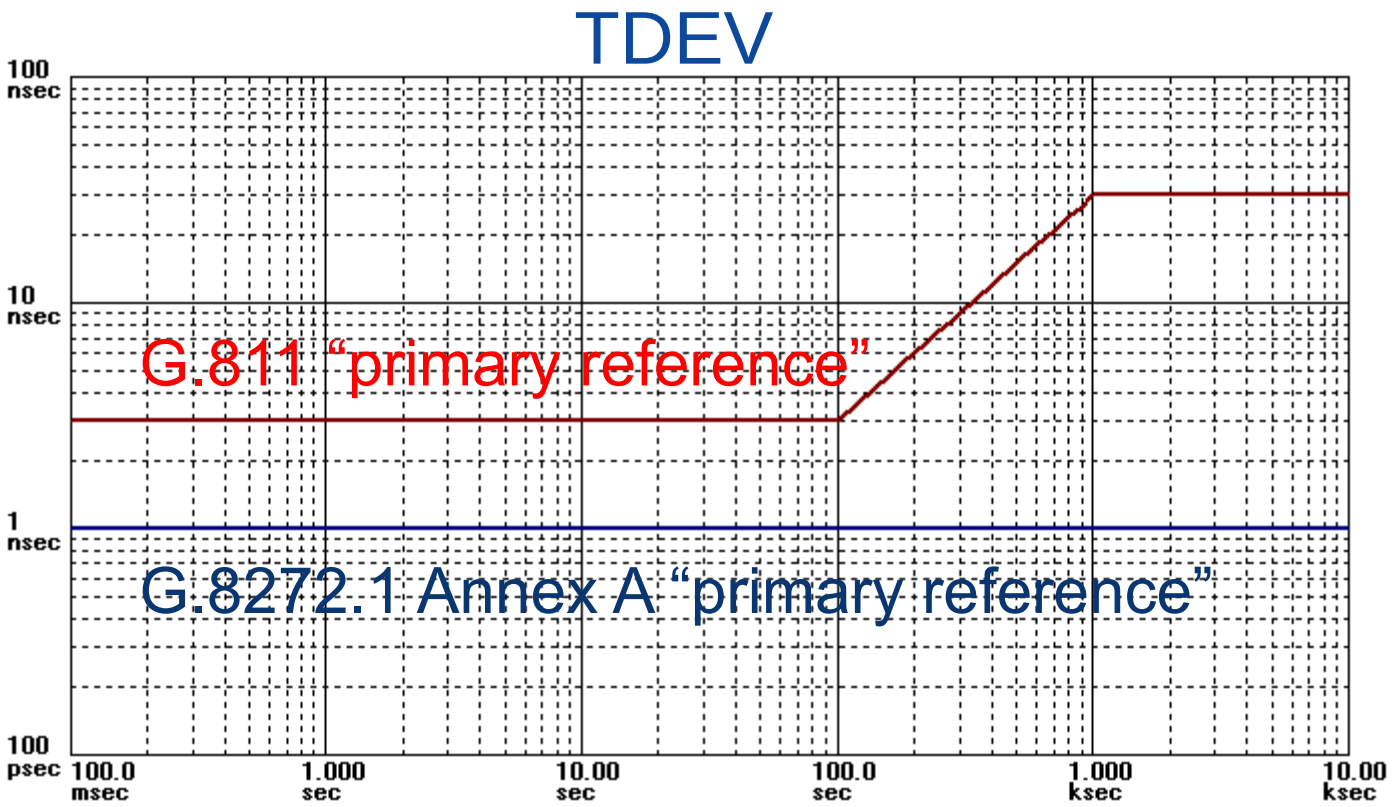
G.703

- G.703 Clause 19 defines rise/fall times and other physical signal characteristics for the V.11 and 50Ω signals, as well as the RJ-45 connector for the V.11 signal.

G.8272.1

- G.8272.1 places additional requirements on the time/phase V.11 interface defined above when used with the ePRTC. In particular:
  - V.11 interface cable should be a high quality cable with a length ≤ 5m, and
    - The 1 PPS signal generation accuracy of the timing master tolerance is ±4 ns
    - The cable delay compensation accuracy tolerance is ±2 ns
    - The 1 PPS signal detection accuracy at the slave tolerance is ±4 ns

ePRTC “Autonomous PRC” vs. G.811 PRC



- G.811 clock requirements do not meet G.8272.1 “autonomous primary reference” requirements
- This led to the necessity of defining a TDEV requirement in G.8272.1 Annex A
- Essentially a new ITU-T “primary reference clock” is being defined, the “ePRC”

ePRC G.811.1

- Just like new clock requirements have spawned an ePRTC (G.8272.1) from the PRTC (G.8272), work has begun on a new ePRC (G.811.1) from the PRC (G.811)
- The new ePRTC “autonomous primary reference” G.8272.1 Annex A TDEV requirement is the starting point, and that requirement will move over to the ePRC
- Thus G.8272.1 Annex A will later refer to a new ePRC defined in G.811.1
- Work is currently underway at the ITU-T in the Q13/SG15 group on the G.811.1 ePRC

Summary

- A new ePRTC (enhanced primary reference time clock) has been defined by the ITU in G.8272.1
- It encompasses a time reference (e.g. GNSS) combined with an input from an autonomous primary reference (e.g. cesium clock) to provide high accuracy time, phase, and frequency with high resilience
- Improved ePRC requirements are necessary, with work underway to define an ePRC (enhanced primary reference clock) in G.811.1 to incorporate the ePRC TDEV requirement already in G.8272.1 Annex A
- The “autonomous primary reference” allows for both improved time accuracy and the ability to maintain atomic time during GNSS outages
- Compared to the PRTC, the ePRTC improves time accuracy to ±30ns from ±100ns, has MTIE and TDEV stability requirements better by around an order of magnitude, and adds time holdover requirements

Thank You

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