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SYNCHRONISATION SOURCES FOR TELECOMMUNICATION NETWORKS GENERAL OVERVIEW

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Symmetricom

Overview

What Is A Sync Source

Global Navigation Satellite Systems

Atomic Clocks

Sync Source Performance in Perspective

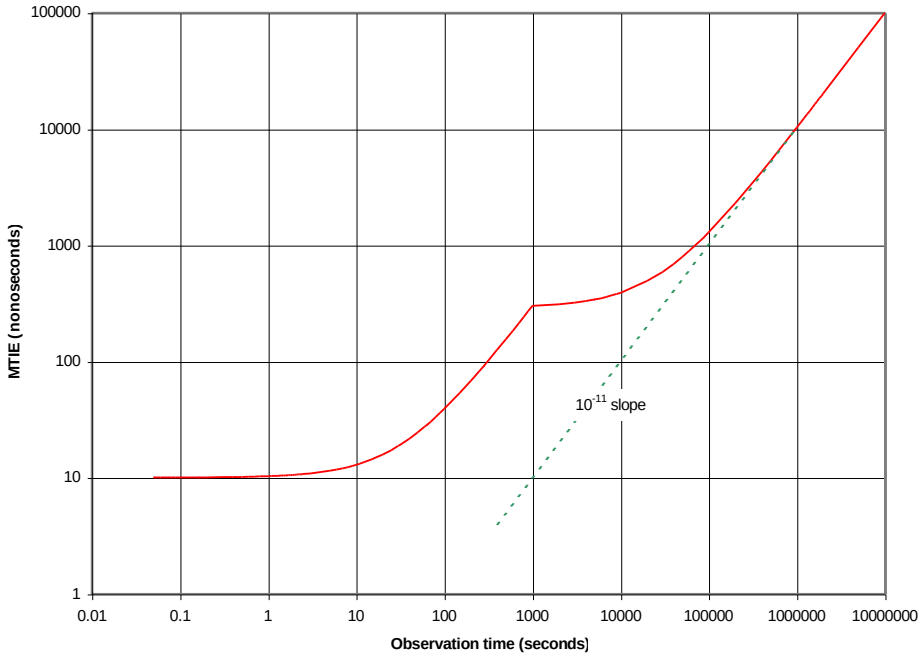
Next Generation Sync Sources

Conclusions

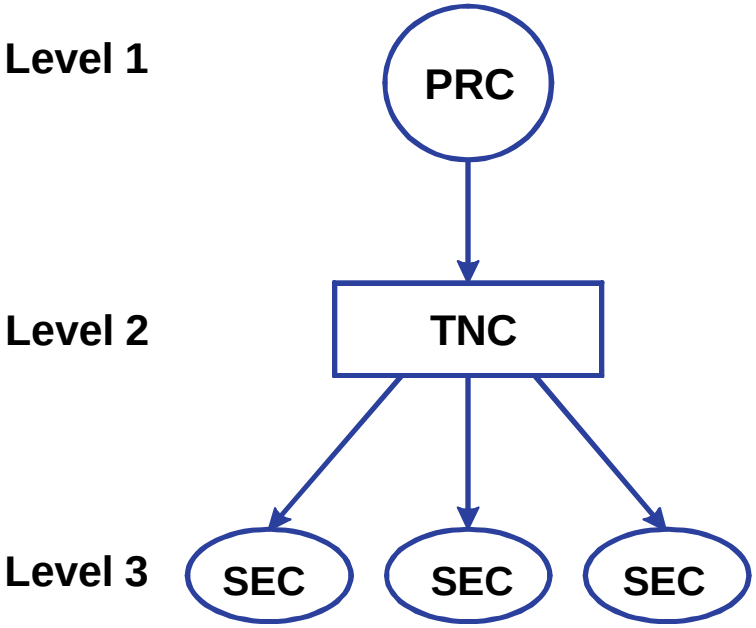
Attributes of Sync Sources

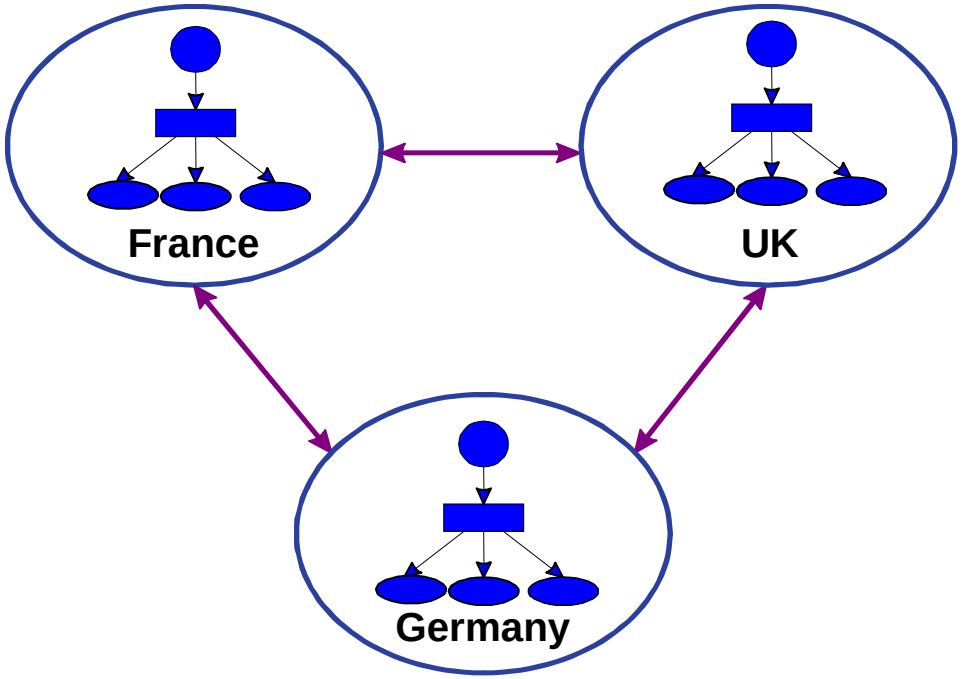
Sync Sources are typically Primary Reference Clocks (PRC's) and must:

- Provide a Stratum 1 reference signal to other clocks within a network.
- Serve as a master clock for a network, network section, office or network element.
- Accurate to 1 part in 10^{11} ($1x10^{-11}$) or better with verification to Universal Coordinated Time (UTC).



ITU-T G.811 / G.803



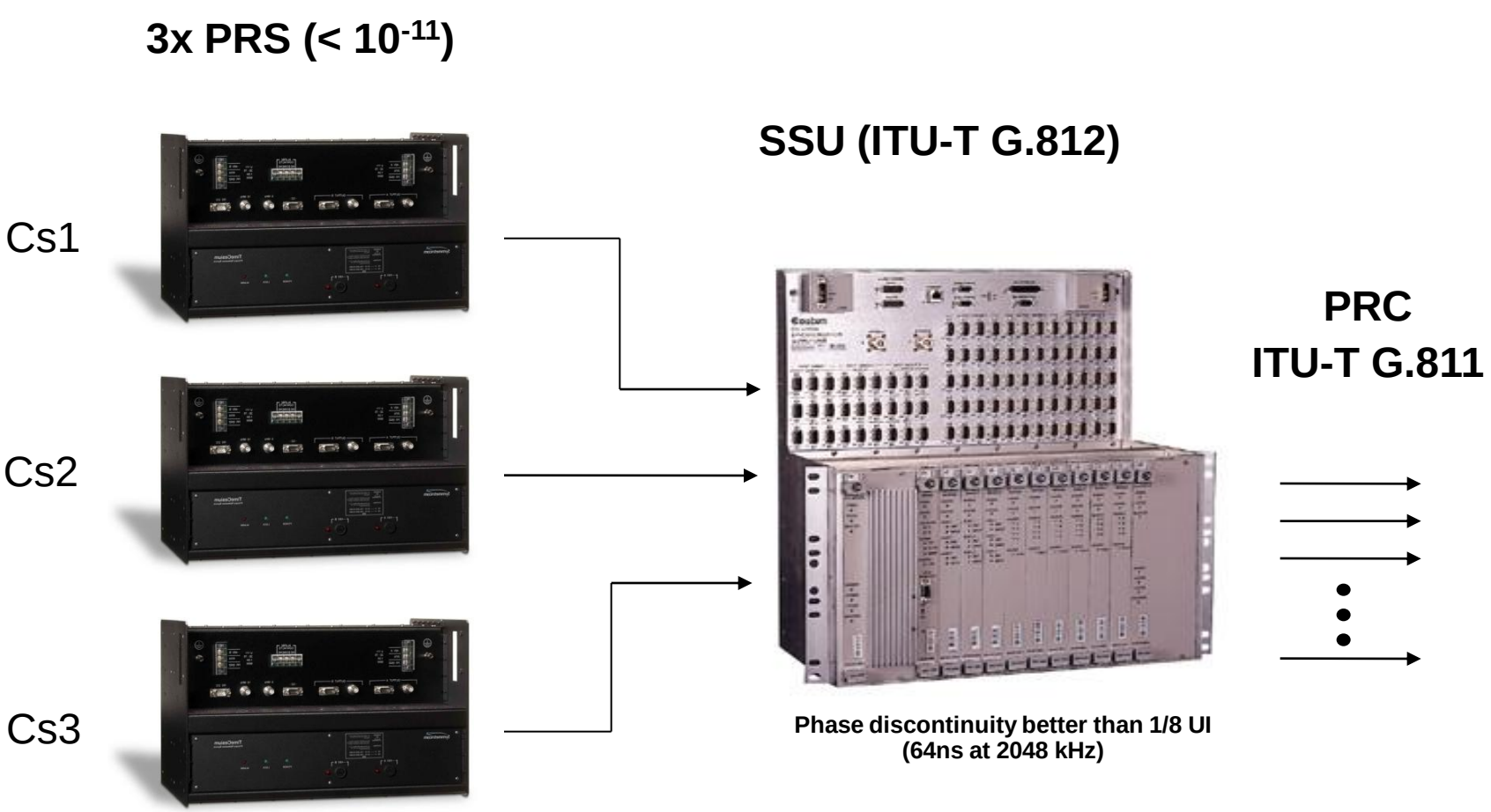


Long term frequency accuracy better than 1 x 10^{-11}

Phase discontinuity better than 1/8 UI (64ns at 2048 kHz)

1 Frame slip in 72 days

Classic PRC per ITU-T G.811



Clock Source Overview

Cesium

Rubidium

GNSS Receivers
GPS, Glonass, Galileo, Compass

Loran C / eLoran Receivers
Long Range Navigation System Vers.C 90 kHz- 110kHz

Long wave Receiver
DCF77(D), MFS (UK), WWVB (US)

CDMA Receiver
Primarily USA

TDM (Frequency)

NGN (Frequency & Time)

Mobile BTS (Wimax/Cellular)

DVA/DVB/DVH
SF MBMS

Power Utility

Military

2048 kHz
2048 kbps

IEEE 1588 (PTP)
NTP
DTI/UTI

1pps
10 MHz

IRIG-B

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Global Navigation Satellite System

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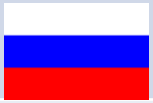
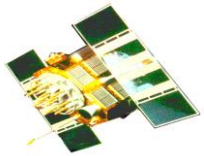
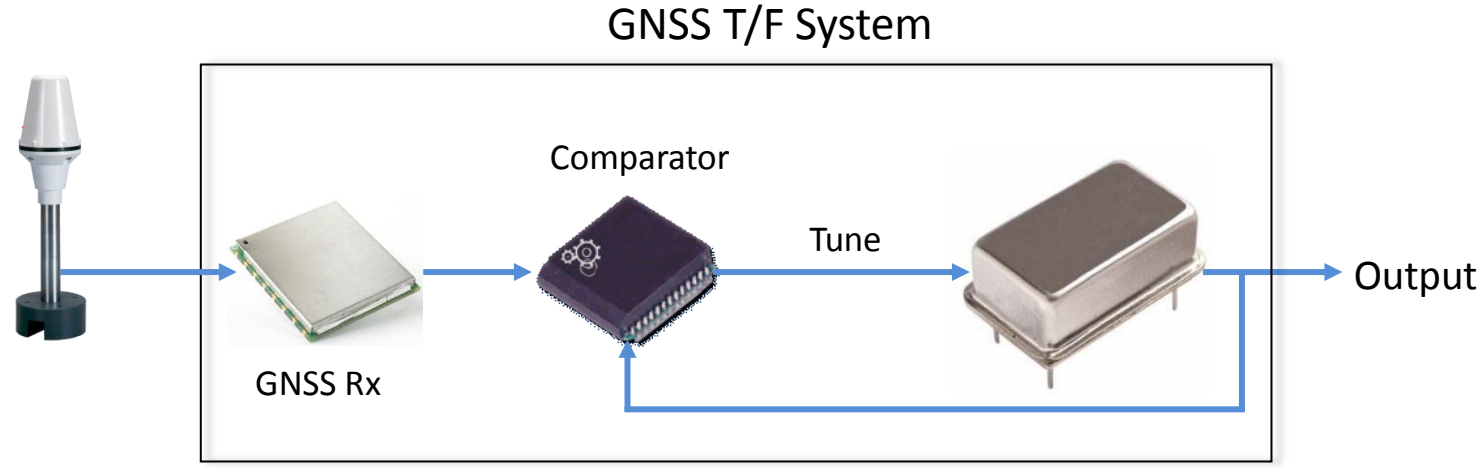
GNSS	GPS	GLONASS	GALILEO	COMPASS (Beidou2)
Country				
Satellites + Spare (Plan)	27 + 3 (1993)	21 + 3 (2012)	26 + 4 (201x)	30 + 5 GEO (2015)
Satellites in Constellation	31 (2009)	19 (2009) 24 (2012) 3Y	2 (2009) 4 (2011) 2Y 18 (2013) 4Y	2(2009) 12 (2011) 2Y 30 (2015) 6Y
Orbital height	20180 km	19100 km	23222 km	21500 km
Orbital period	11:58 h	11:15 h	14.05 h	12:35 h
System Control	Military	Military	Civil	Military
Timing Services	Yes	Yes	Yes	Yes
Clocks	Cs, Rb	Cs	PHM, Rb	Rb
TimeScale	TAI-19	UTC-3 hours	TAI	
Time Offset transmission	GGTO GPS/Galileo Time Offset		GGTO GPS/Galileo Time Offset	
Open service / 95%	100 ns	100 ns	30ns	50ns
Open service / 95%	28m		35m	50m

RNSS Regional Navigation Satellite Systems: QZSS (Japan), IRNSS (India) and Beidou1 (China)

GNSS Time & Frequency System





Pro‘s:
- low cost
- high quality PRS, if stable internal Oscillator used
- provides frequency, time and phase !

Con‘s:
- off air system, need to receive satellite information
- outdoor antenna installation required (may be expensive)
- lightning issues / protection
- system errors may cause large time offsets
  RAIM Receiver Autonomous Integrity Monitoring doesn’t prevent for all errors !
- Jamming

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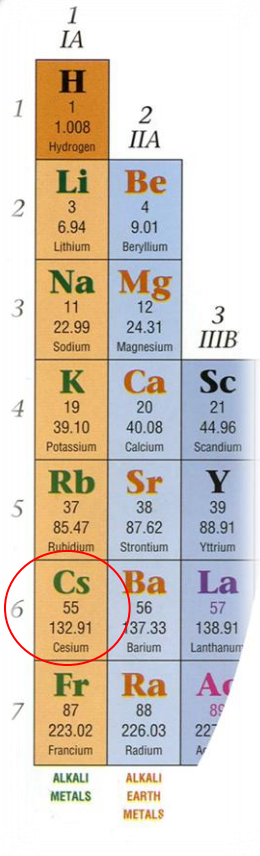
Cesium atomic clock autonomous PRS

Telecom Cs / ETSI / 12 years tube

famous 5071A Cs
80% weight in UTC



Pro‘s:
- strategic independent, autonomous high quality PRS (x 10^{-12})
- up and running within 30 minutes after power on
- no external reference signals required
- no antenna installations required
- long life time tubes, warranty up to 12 years
- Cesium beam no frequency aging behavior (Rb, Maser age)
- self controlled, alarm indication

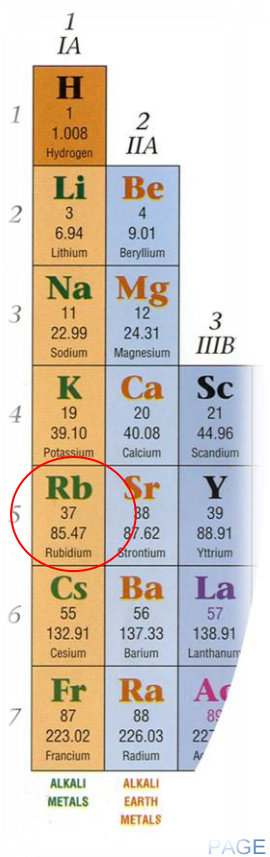
Con‘s:
- expensive compared to GNSS Receiver
- Cs beam tube needs to be replaced after 12 years typical
- ToD outputs require initial time synchronization

Rubidium Atomic Clocks
Almost a Primary Reference Source

Use:
- Versatile frequency source for many commercial, telecommunication & aerospace applications
- first atomic clock in space
- meets lifetime mobile basestation holdover
- perfect Osc. inside GNSS & SSU systems

Pro's:
- small, light, low cost, low power atomic clock
- fast warm up (7 minutes)
- excellent retracibility
- unlimited lifetime (physics doesn't limit lifetime)
- self controlled, alarm indication
- 3-6 weeks network holdover
- very good short term stability

Con's:
- doesn't meet PRS stability specification
- Rubidium typical frequency aging of 1 to 5e-11/month
- initial factory calibration / aging correction required



Other Atomic Clocks

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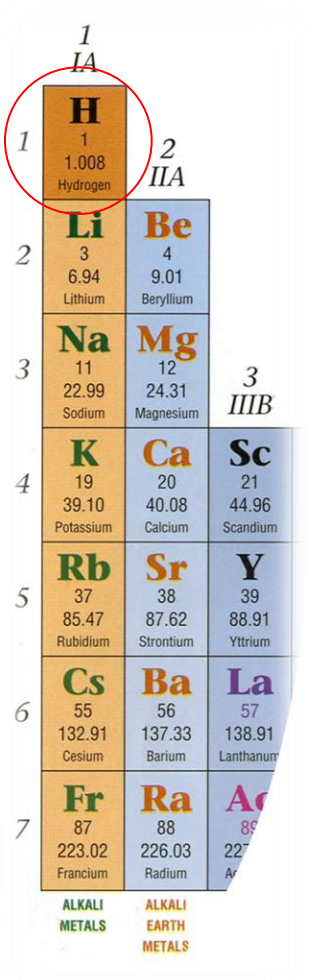
Active Hydrogen Maser (AHM)

- Uses intrinsic properties of the hydrogen atom.
- Best short term frequency stability
- Frequency stability is ~40X superior to cesium
- Relatively large, complex and expensive
- Used for maximum stability
  (Master Ground Stations for GNSS,
  National standards, radio ground stations,
  and very long baseline interferrometry).



Passive Hydrogen Maser (PHM)

- Uses intrinsic properties of the hydrogen atom.
- The cavity is fed by an external 1420 MHz frequency (passive vs. active) that is tuned to produce the maximum output in the cavity.
- Frequency stability comparable to lower Cesium
- H_2 replenishment after 4-6 years.
- Passive Maser show frequency aging behavior, therefore is not a good standalone PRS

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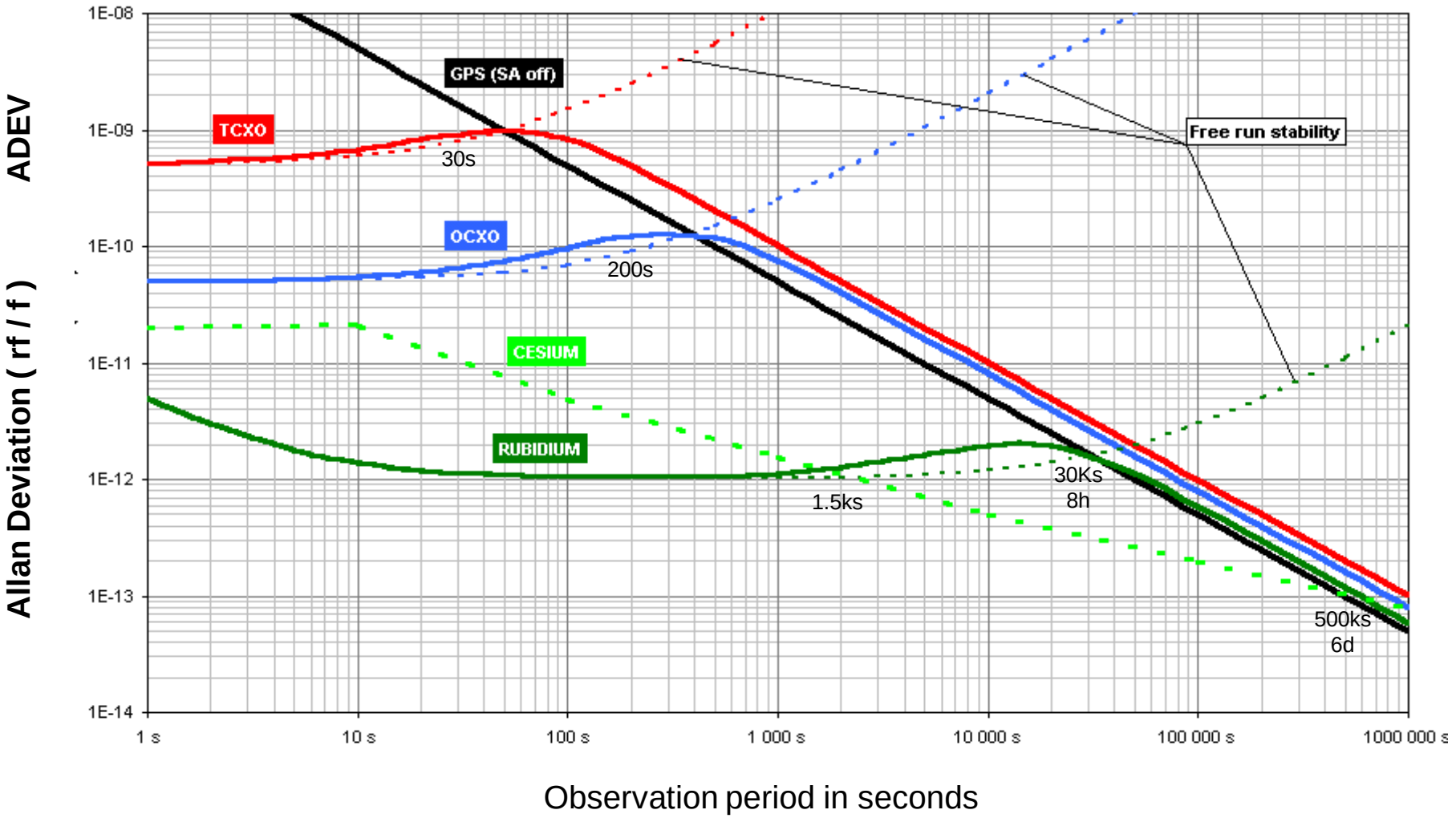
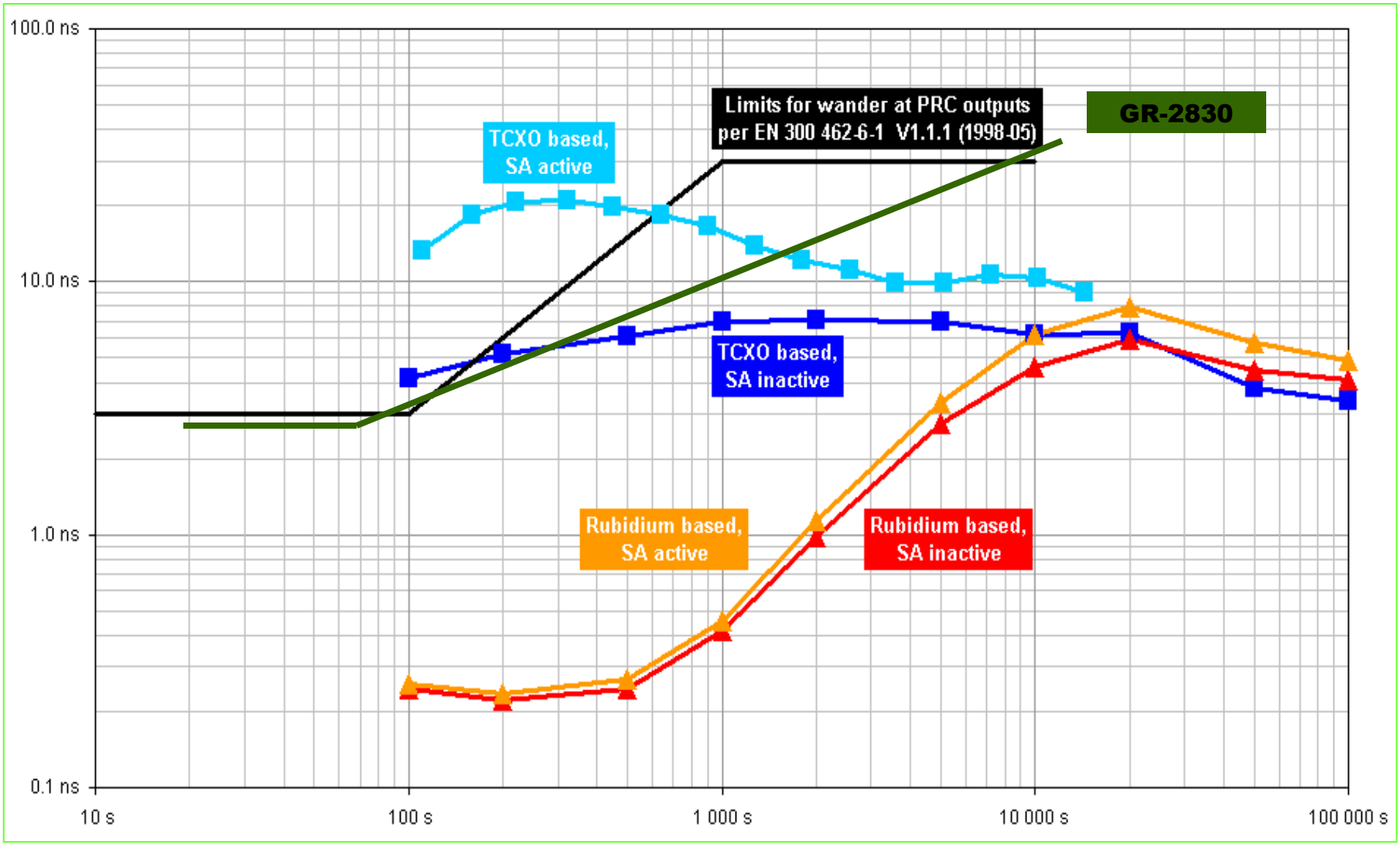
Oscillator Stability versus GPS



GPS PRC stability with SA on / off



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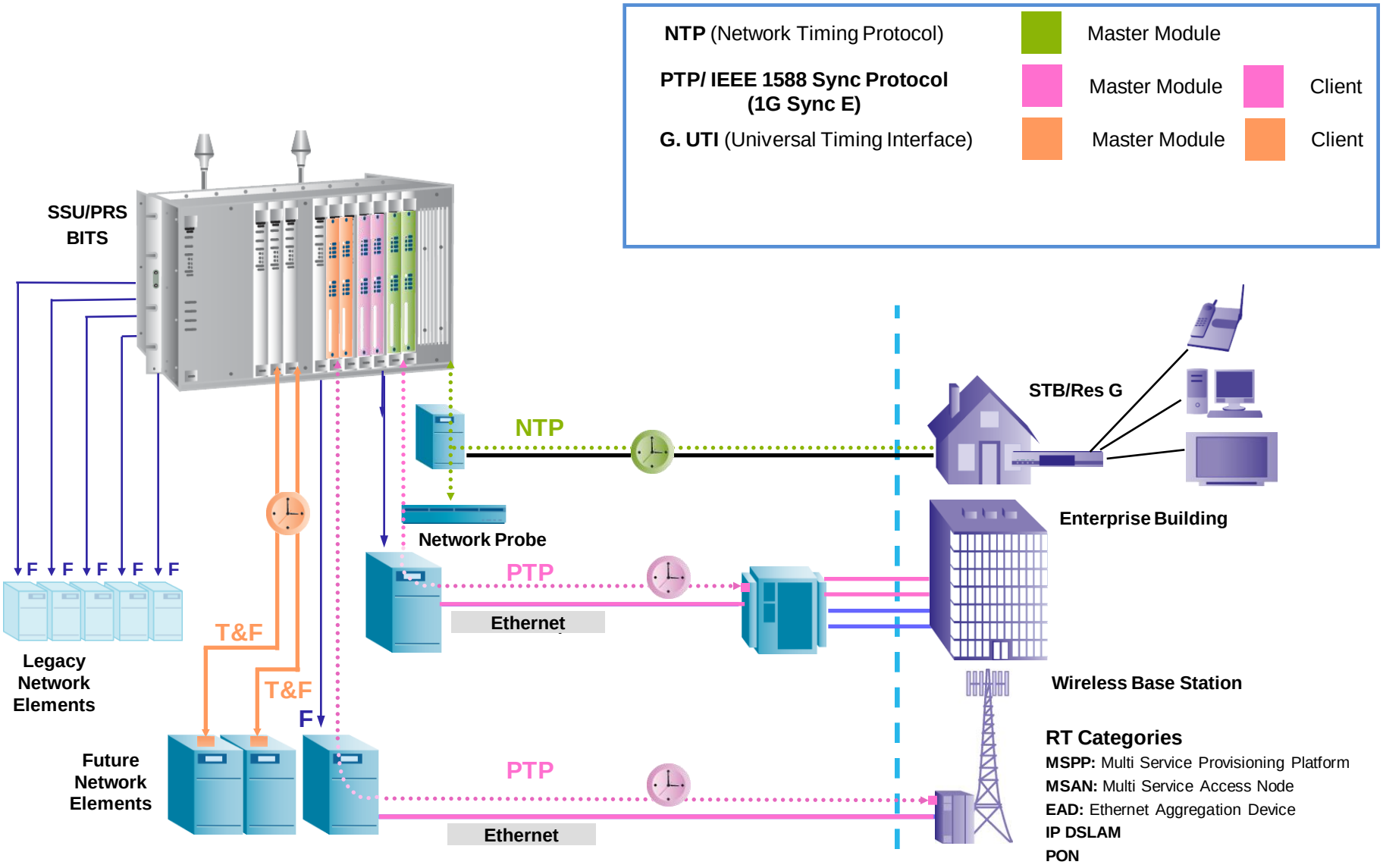
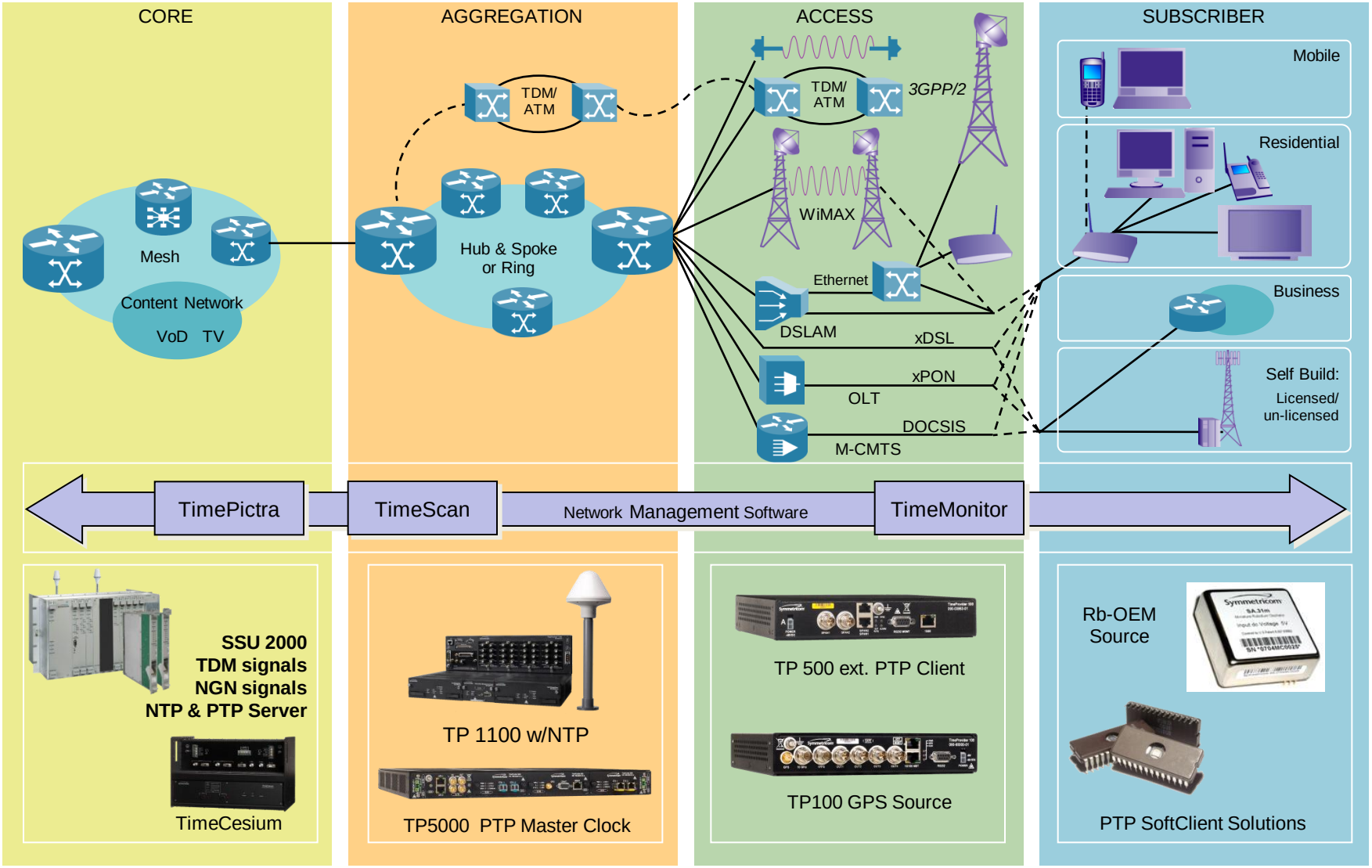
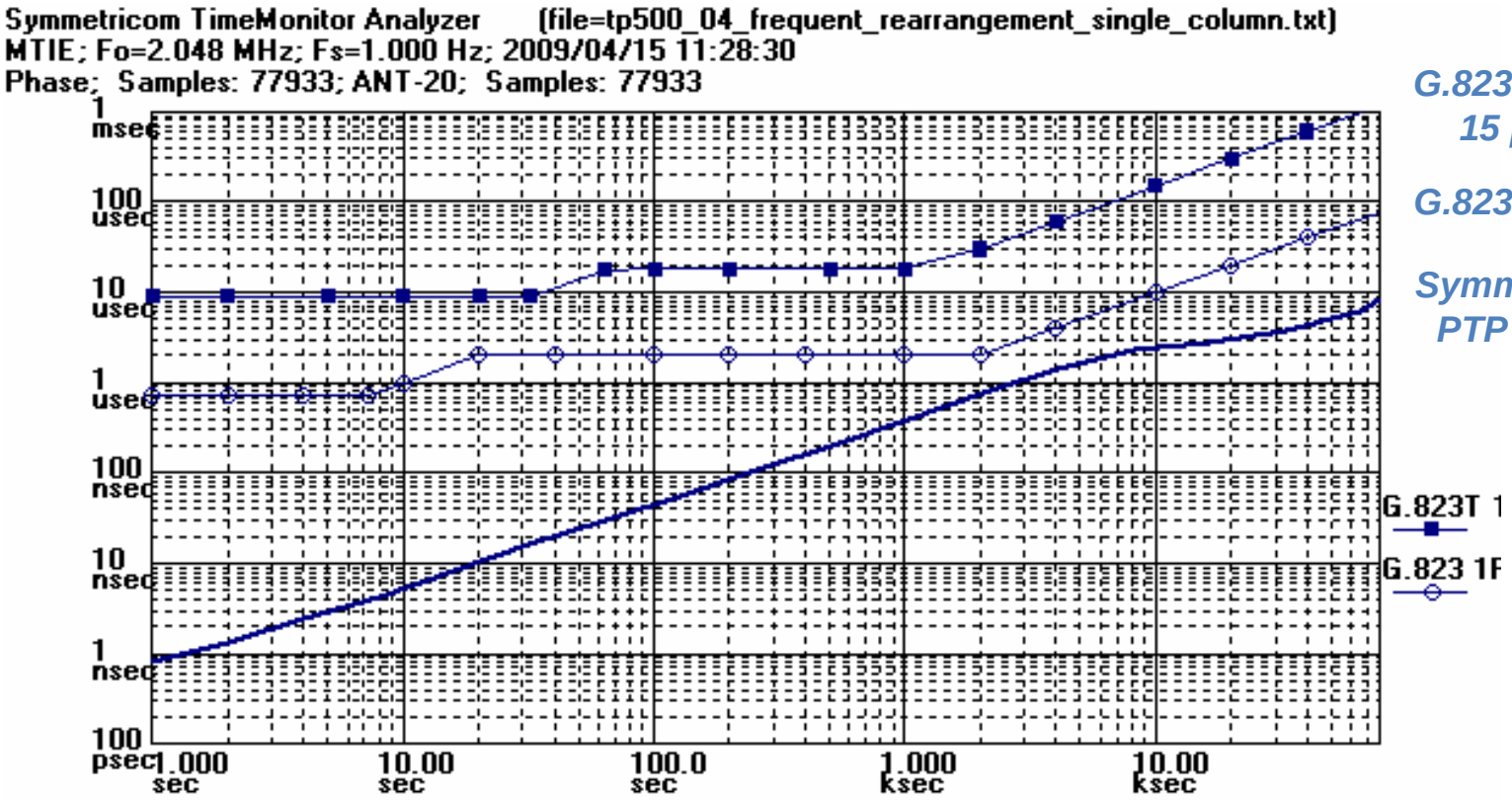
NGN PRS Sync Source



Sync Sources in the NGN Network



PTP client sample field data – MTIE



G.823 traffic 15 ppb

G.823 1 ppb

SymmTP500 PTP client

Live deployed network in Europe

- Sync was tested over Packet-over-SDH, 2 weeks
- Moderately loaded network ring (7 hops in one direction, 15 hops in the other)
- Meeting G.823 sync mask + 1ppb with large margin

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- **Cesium**
  - Until mid 90s Cesium was the choice as PRS
  - Today Tier 1 and national operators use Cs as PRS for strategic / political reasons
- **GPS**
  - since beginning 90s continuously stable open service, the last years w/o SA
  - deregulated telecom market generated high demand on PRS's, due cost reasons GPS disciplined PRS became very popular !
  - By now the most deployed PRS in Telecom Networks (at the beginning NO trust in GPS, today too much trust !!)
- **GNSS**
  - GPSIII, Glonass, Galileo, Compass provide many Satellites to choose from
  - new signals, more accuracy, integrity information, higher signal strength
  - interoperability

Interoperable multi GNSS Receiver will become the ultimate PRS Sync Source

Timing protocols like PTP will provide virtual sync sources throughout the IP NGN

Thank You For Your Time …

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