Synchronization Protection & Redundancy in NG Networks

June 2016

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WSTS 2016

What can possibly go wrong … ?

- GNSS failure
  - Jamming (intentional and unintentional)
  - Antenna breakdown (lightning , cable cut)
- Equipment failure
  - HW failure
- Connectivity to GM is lost
  - Network outage or extreme overload

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GPS “availability issues” Feb 2016

According to the US Air Force (USAF), which manages the GPS satellite network, problems began when a satellite named SVN 23 was decommissioned.

A USAF spokeswoman confirmed that the error had been pushed to the satellites by "ground system software".


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Technology

GPS error caused '12 hours of problems' for companies

By Chris Baraniuk
Technology reporter

4 February 2016 | Technology

Thinkstock

System engineers were "called out of bed" over the problems

Several companies were hit by hours of system warnings after 15 GPS satellites broadcast the wrong time, according to time-monitoring company

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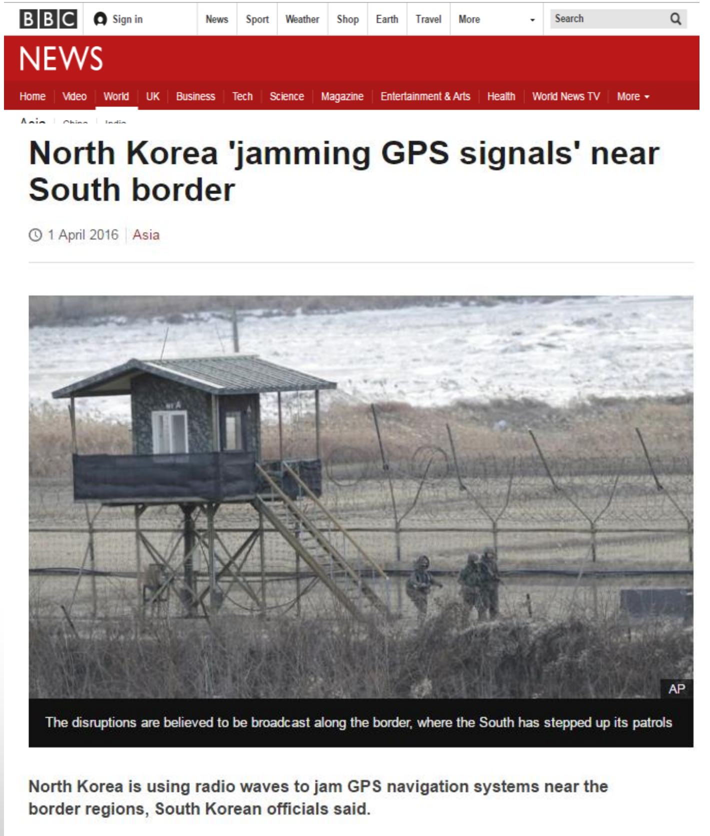
GPS “availability issues” April 2016

“North Korea is using radio waves to jam GPS navigation systems near the border regions, South Korean officials said.”

“The broadcasts have reportedly affected 110 planes and ships, and can cause mobile phones to malfunction.”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North Korea 'jamming GPS signals' near South border

1 April 2016 | Asia

AP

The disruptions are believed to be broadcast along the border, where the South has stepped up its patrols

North Korea is using radio waves to jam GPS navigation systems near the border regions, South Korean officials said.

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Protection and Redundancy Options:

- Protection at **Slave/BC side** – switching to a standby GM based on the relevant Best Master Clock Algorithm (BMCA)
  - May results network rearrangement
  - Switching between GM's may results phase transient
- Protection at **Master side** – GM switching to secondary source in case the primary source fails
  - Might prevent network rearrangement if secondary source if sufficiently good

Both options can be combined in
order to achieve best protection & redundancy

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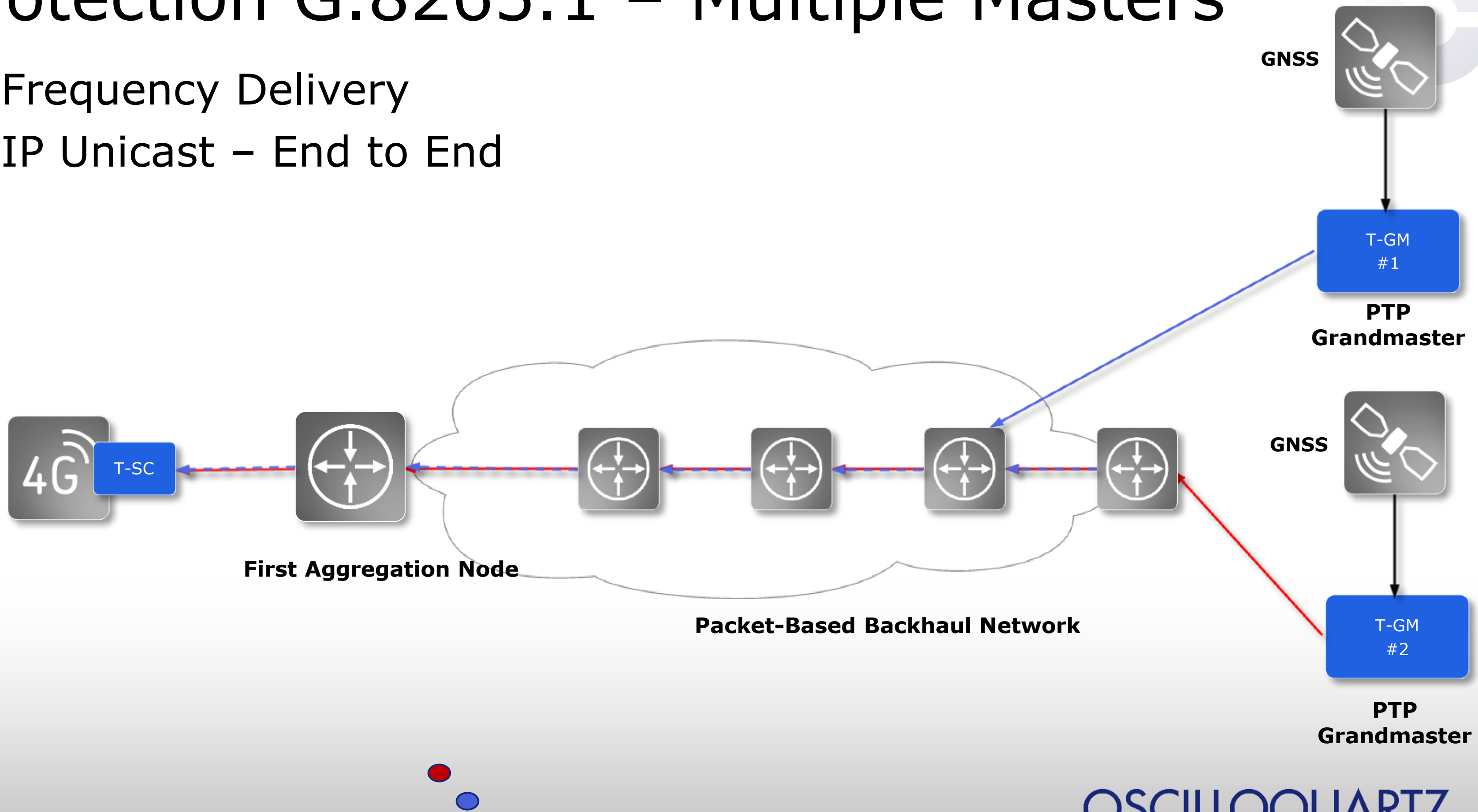
Protection G.8265.1 – Multiple Masters

- Frequency Delivery
- IP Unicast – End to End



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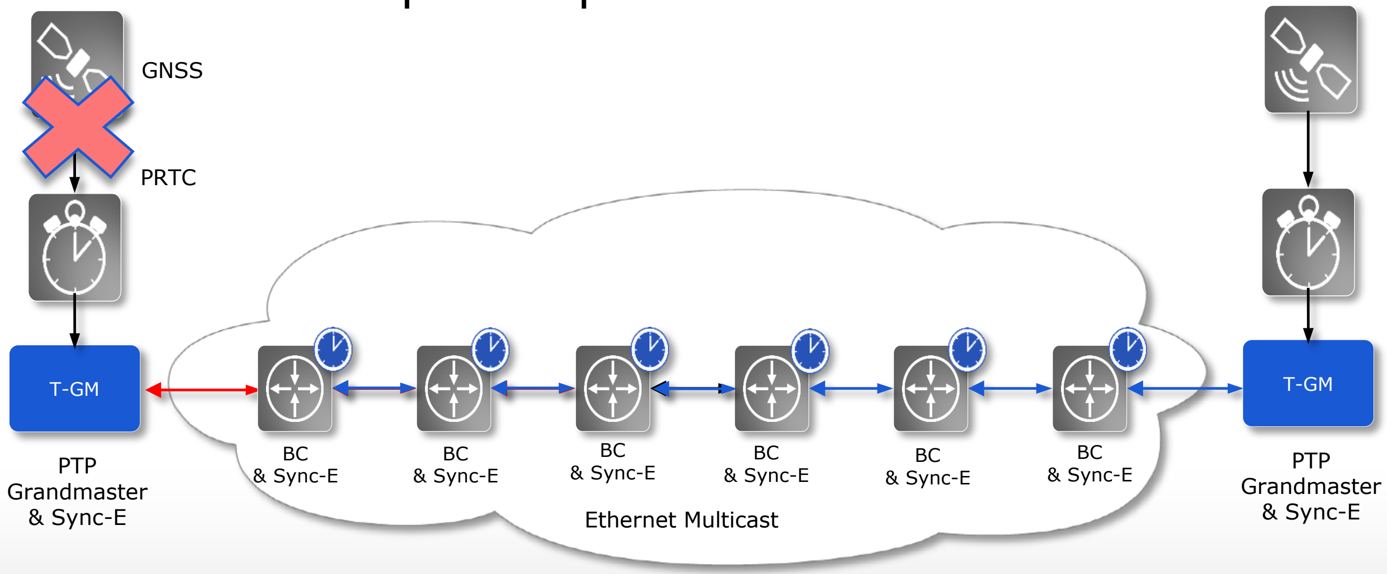
Protection G.8275.1 – Multiple Masters

- Phase & Frequency Delivery
- Eth’ Multicast – Hop to Hop



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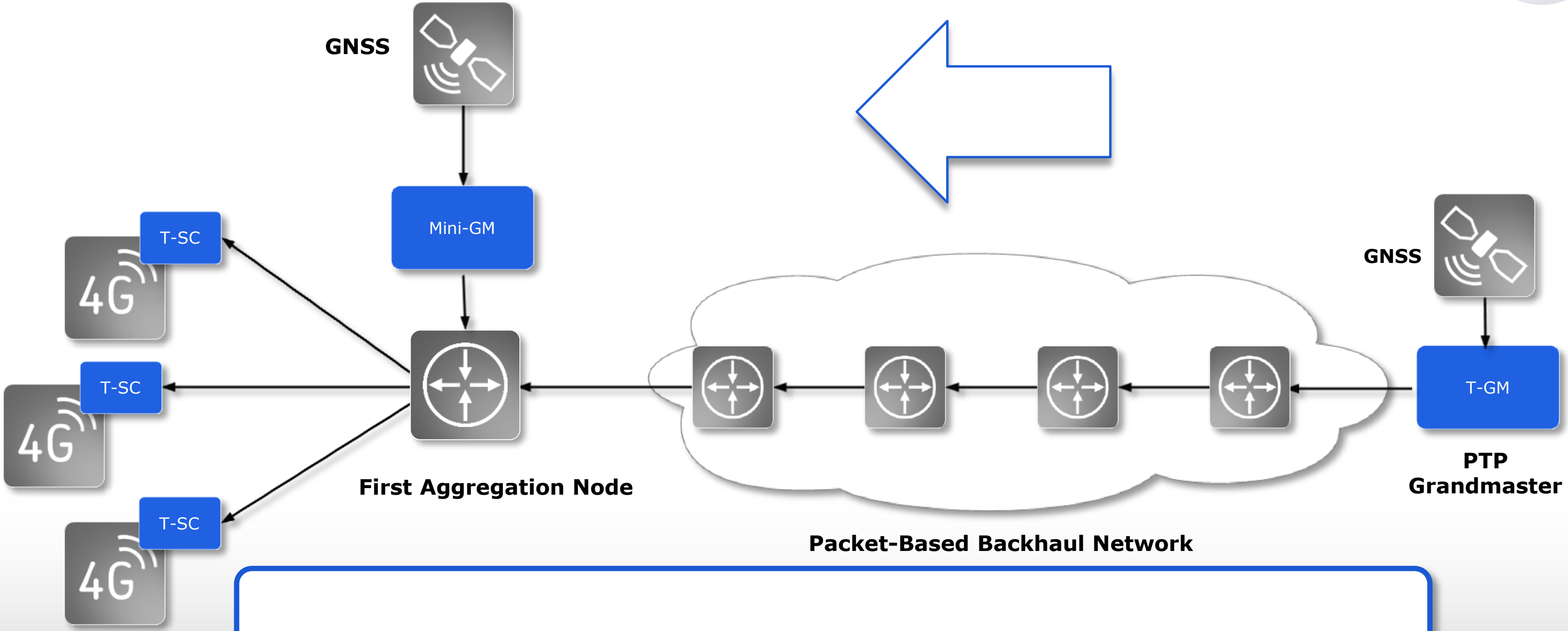
Distributed Architecture Using Mini-GM



GM are getting closer to network edge

Distributed GM Protection Options

- What if GNSS is locally in outage (e.g. Jammed)

1. Physical layer input
   - Sync-E
   - BITS
   - Can be a good option – but not always available
2. PTP input (APTS)
   - Recovering both frequency and phase
   - Recovering only frequency which is used for phase holdover
   - Will be reviewed in details in Dominik presentation
3. **Holdover based on local oscillator**
   - Always available
   - **Oscillators technology have made a long way since the first Quartz clock -1927**

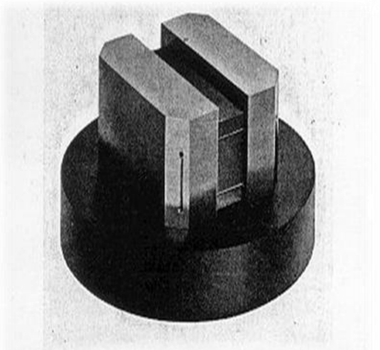
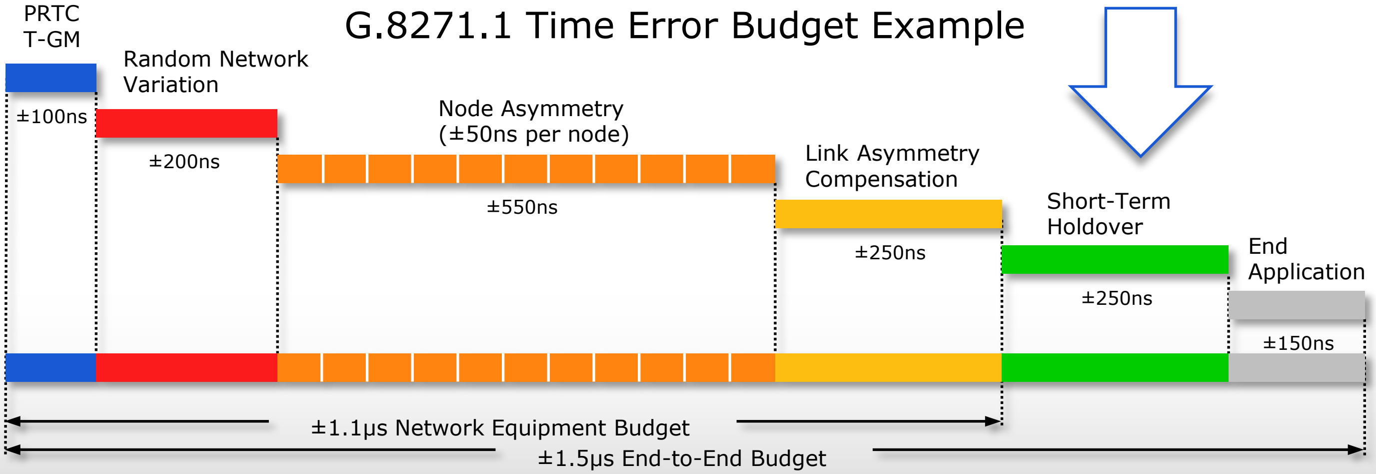


Fig. 10—50,000-Cycle quartz resonator, in original mounting, used in first quart[z] [cl]ock—1927.

Short Term Holdover

- e.g. Temporary GNSS jamming or poor line of sight
- Duration : Few seconds – Few hours
- Holdover budget – few hundred of nsec



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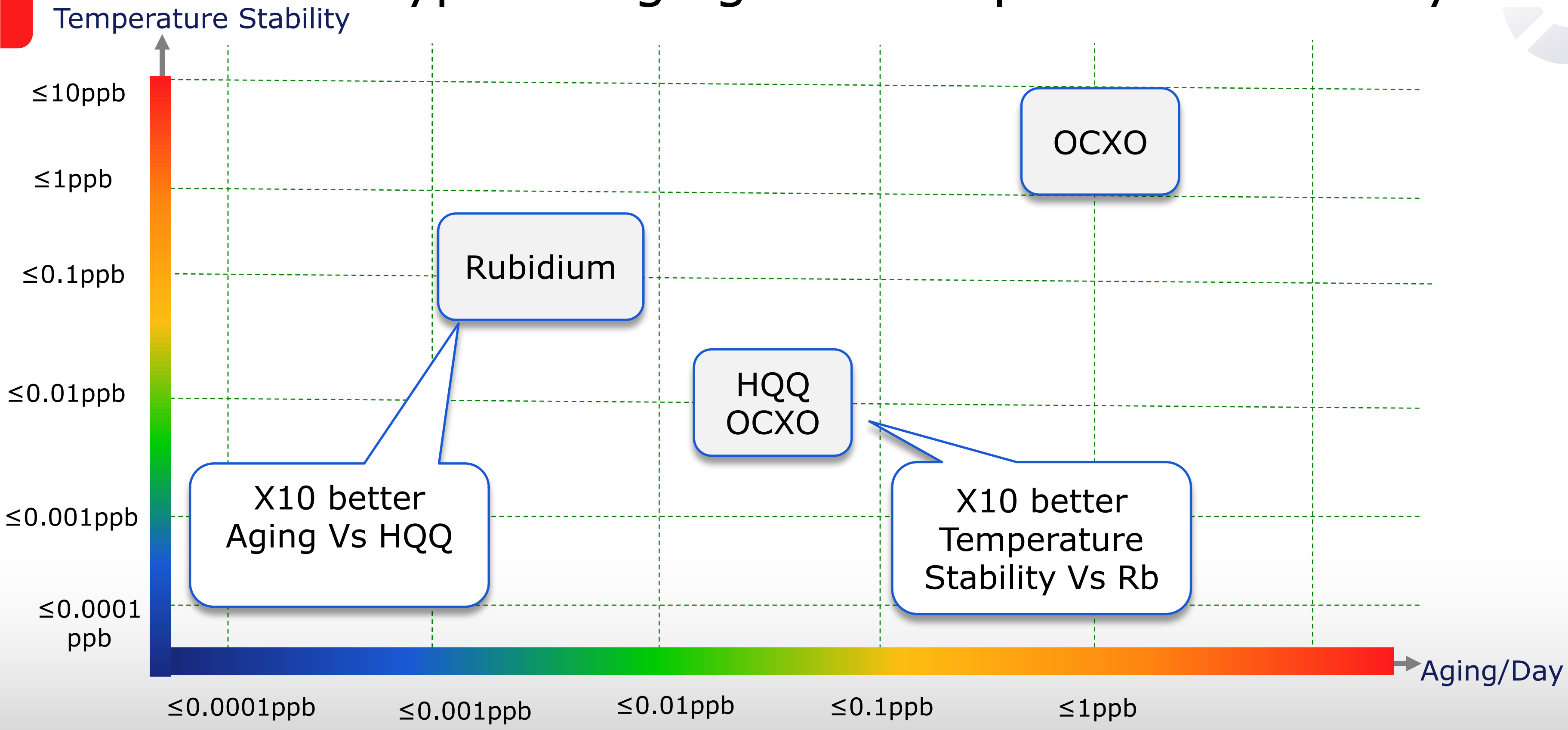
Long Term Holdover

- Antenna failure (e.g. lightening)
- Few hours – 3 days
- Depend on the available time error budget – but potentially can be more than 1500nsec

Oscillator Types – Aging and Temperature Stability



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It can be very cold…

HUAWEI BS China 2008
winter storm

Telenor base station or snow creature?

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Or very hot…

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And it can swing in between…

- The greatest temperature change in 24 hours occurred in Loma, MT. on January 15, 1972. **The temperature rose 56 degrees**, from -47C (-52.6F) degrees to 9C (48.2F) .
- The greatest temperature change in 12 hours happened on December 14, 1924. The temperature at Fairfield, Montana, dropped from **17C (62.6F) to -29 (-20.2)** at midnight (D**elta of 46C**)

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Environmental Condition

- Synchronization devices at the access networks are subject to wider temperature variation!
- ETSI Environmental Classes:

	Class #	Class description	Temp. change rate	Temp. change range	Delta
Core	3.6	Control room locations	0.5°C / min	[+25, +30°C]	5°C
	3.1	Temp. controlled locations	0.5°C / min	[+25, +40°C]	15
	3.2	Partly temp. controlled locations	**0.5°C / min**	**[+25, +55°C]**	**30**
	3.3	Not temp. controlled locations	**0.5°C / min**	**[-5, +45°C]**	**50**
Access	4.1	Non-weatherprotected locations	**0.5°C / min**	**[-10, +40°C]**	**50**
	3.5	Sheltered locations	**1°C / min**	**[-40, +40°C]**	**80**

	Ethernet Access NE - typical operational temperature range		**[-40, +65°C]**	

Higher temperatures are expected in other continents

Oscillator Types

Clock Type #	Cost	Operational Temperature range of the clock	Typical Ambient Operational Temperature range of the Sync Element	Temp Stability	Aging/Day
OCXO	Low (10%)	-40 to 85 C	-40 to 65 C	1-10 ppb	1ppb
OCXO HQ	Medium (100%)	-40 to 85 C	-40 to 65 C	0.01 ppb	0.05 ppb
Rubidium	High (300%)	-10 to +75 C	-5 to +55 C	0.1 ppb	0.005 ppb

But Aging can be estimated with GNSS!

Rb High cost , limited operational temperature range and temperature instability make it less suitable for access devices

Aging seem to be the only advantage of Rb

Comparing Leading Rubidium Suppliers:

Clock Type #	Cost	Operational Temperature range of the clock	Typical Ambient Operational Temperature range of the Sync Element	Temp Stability
OCXO HQ	Medium (100%)	-40 to 85 C	-40 to 65 C	0.01 ppb
Rubidium Vendor A (Market leader)	High (400%)	-10 to +75 C	-5 to +55 C	0.1 ppb
Rubidium Vendor B	High (300%)	-30 to 65	-5 to +50 C	0.5 ppb
Rubidium Vendor C	High (300%)	-20 to 65	0 to +50 C	0.5 ppb

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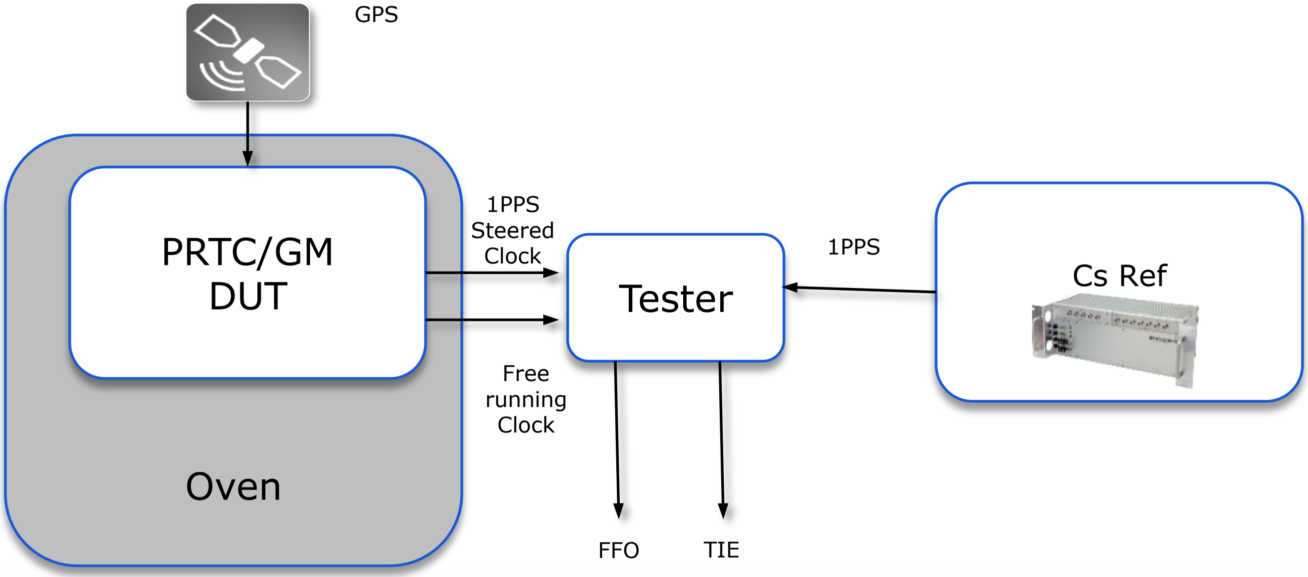
Ideal Condition for Efficient Learning

- **Good teacher** : GPS (GNSS long term accuracy is better than 1e-12)
- **No disturbances**: temperature effect are isolated by using very high quality quartz oscillator

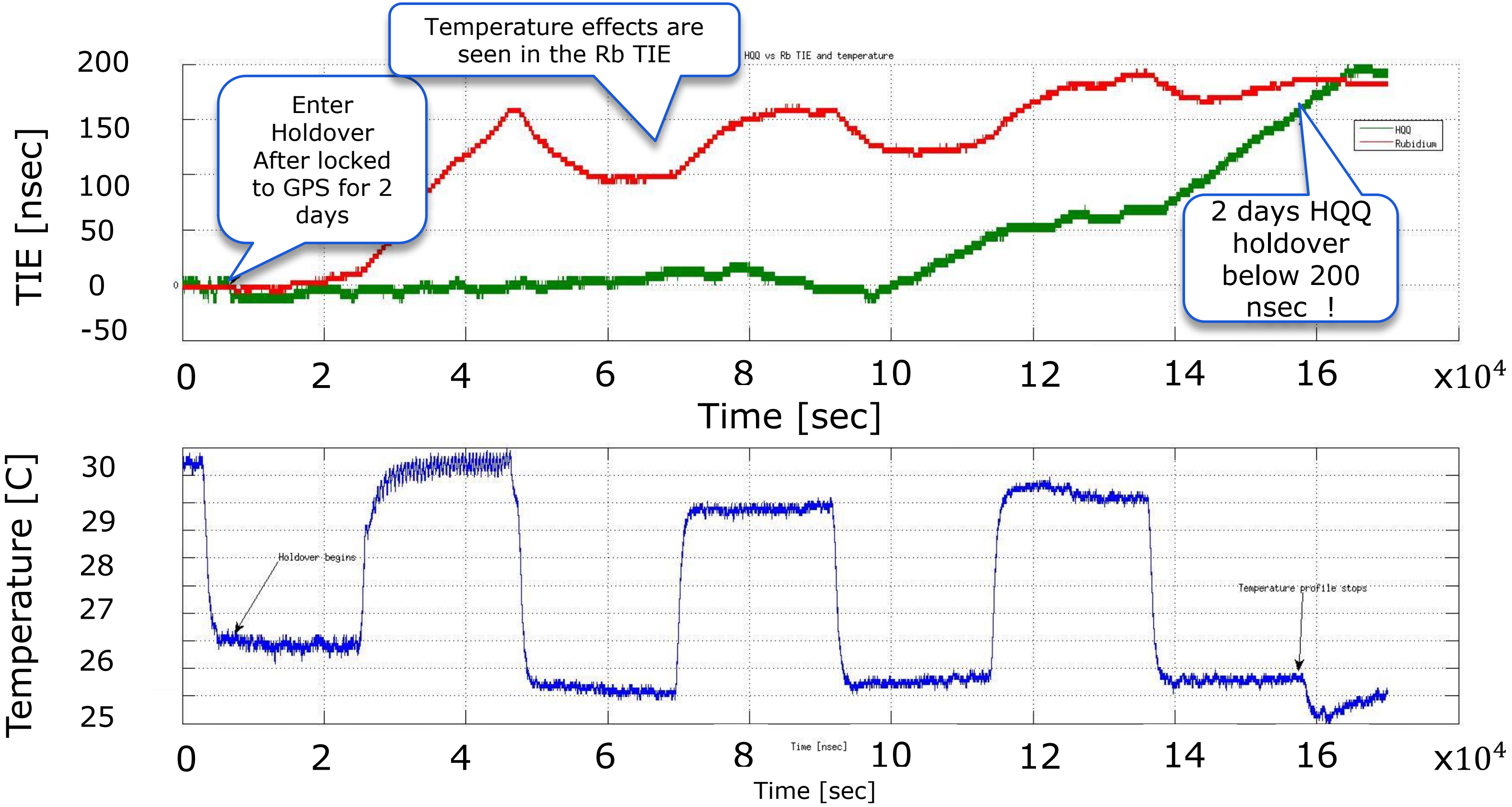
GPS as reference HQ oscillator → Learn aging characteristics while GPS available → Use these characteristics while in holdover

Combining OSC high temperature stability with GPS reference generate optimized solution in both performance and cost

Test Setup

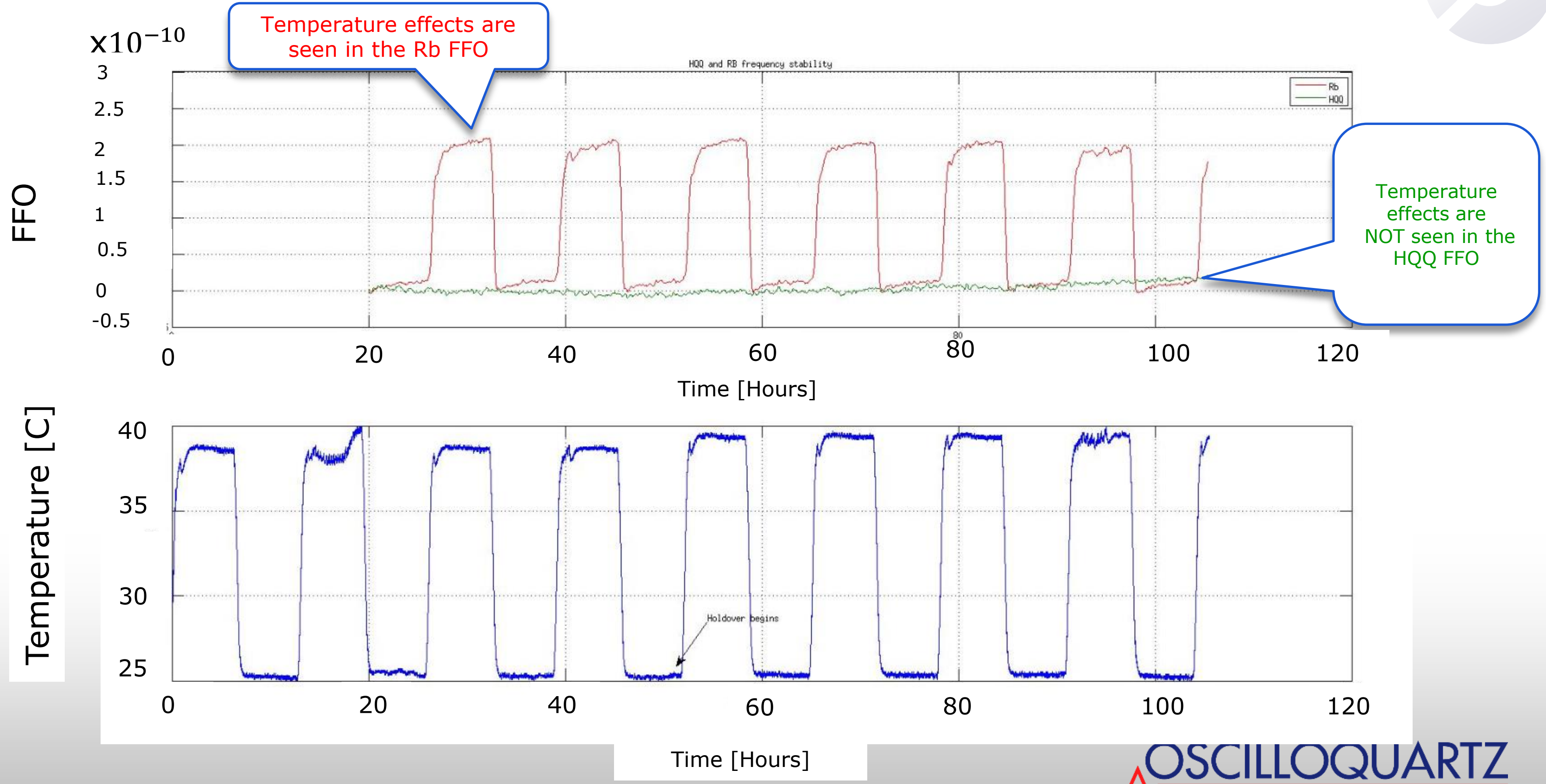

GPS
PRTC/GM
DUT
Oven
1PPS
Steered
Clock
Free
running
Clock
Tester
1PPS
Cs Ref
FFO
TIE

HQQ Vs Rb – Controlled Room (25-30C)



- Tested in the Oven with controlled room profile
- Phase Holdover over 48 hours below 200nsec !

HQQ Vs Rb – Temp' Controlled Room (25-40C)



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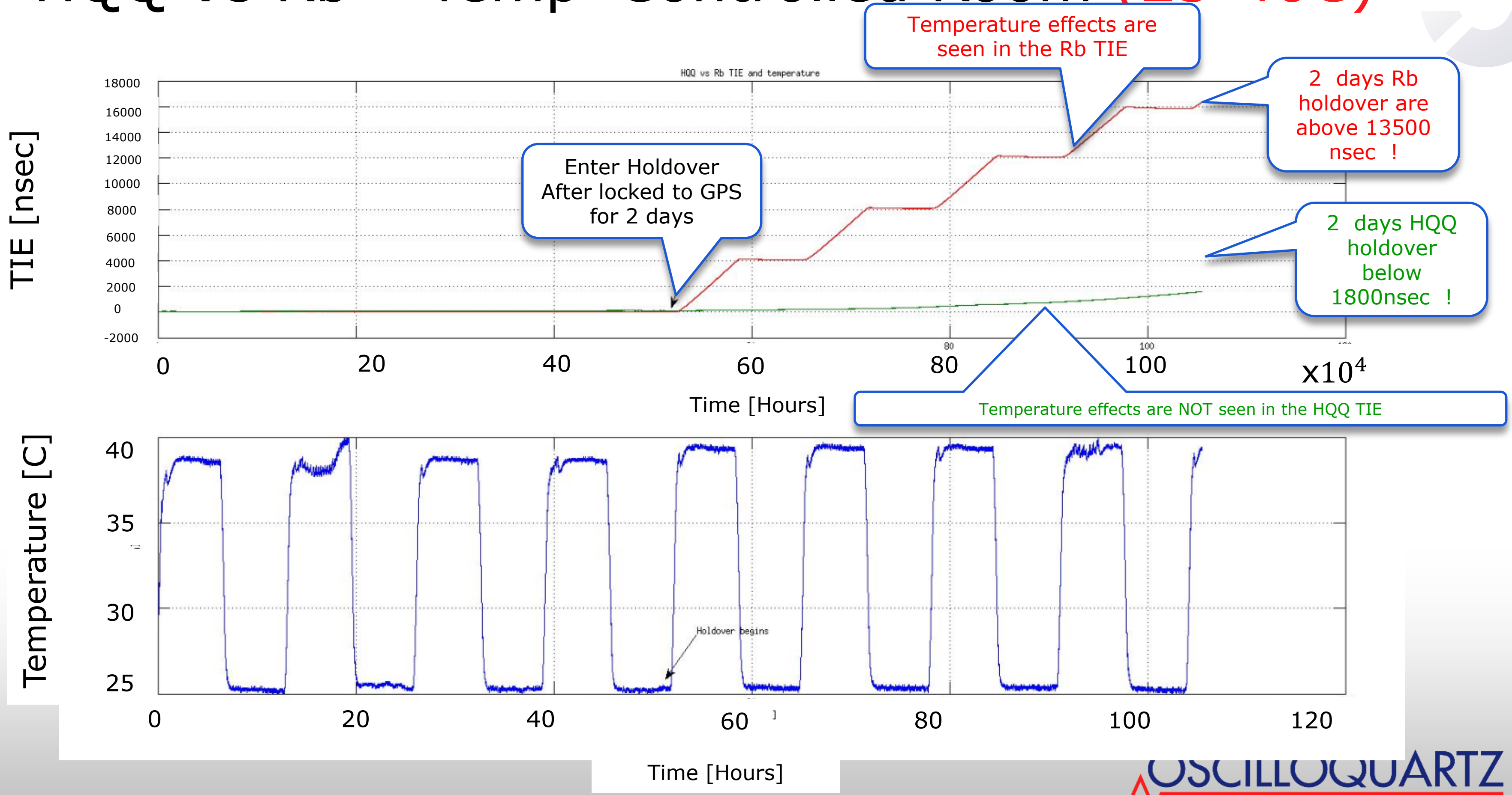
HQQ Vs Rb – Temp' Controlled Room (25-40C)



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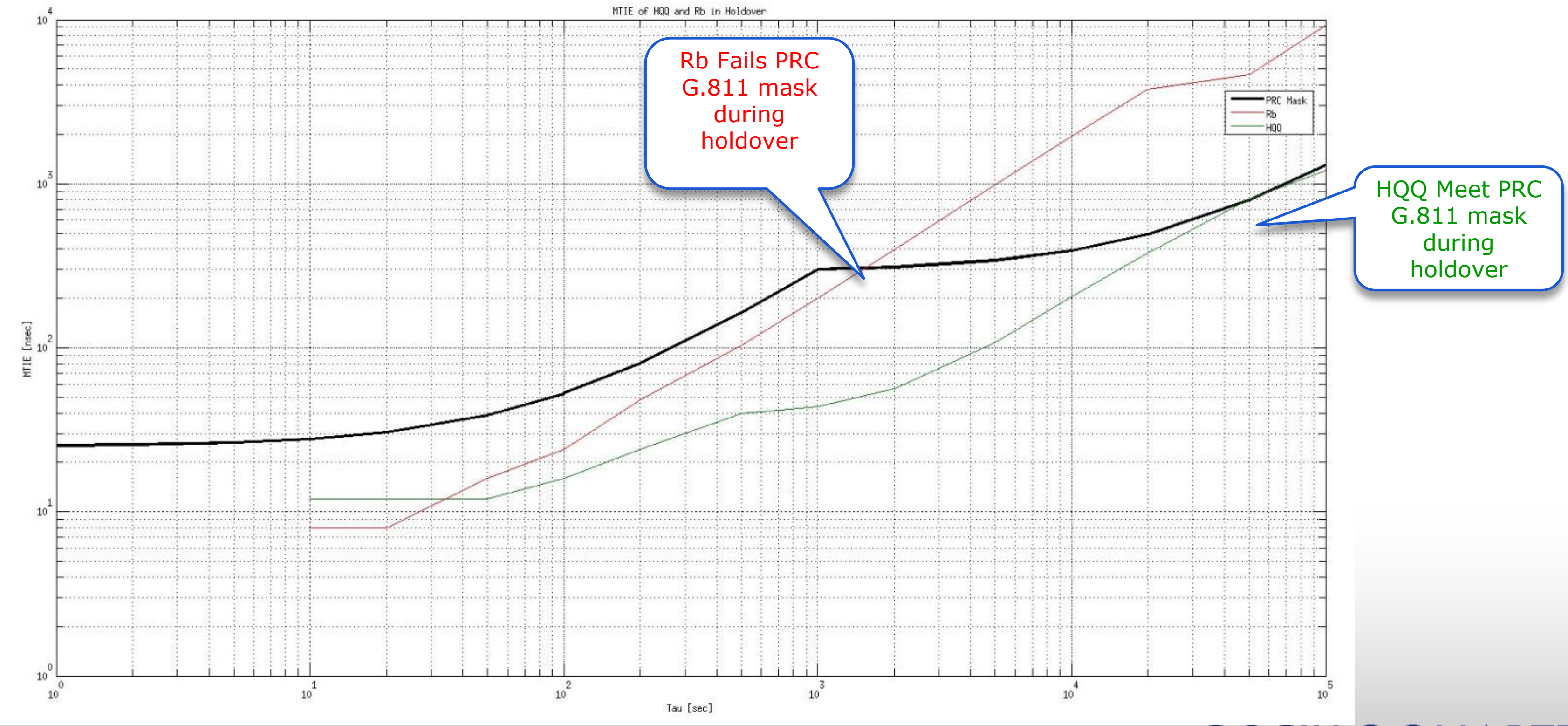
HQQ Vs Rb – Temp' Controlled Room (25-40C)



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Best Rb Supplier Tested at 35-50C

FFO

0.1ppb pk2pk – worst case TE of 360nsec/hour!

Temperature [C]

50

45

40

35

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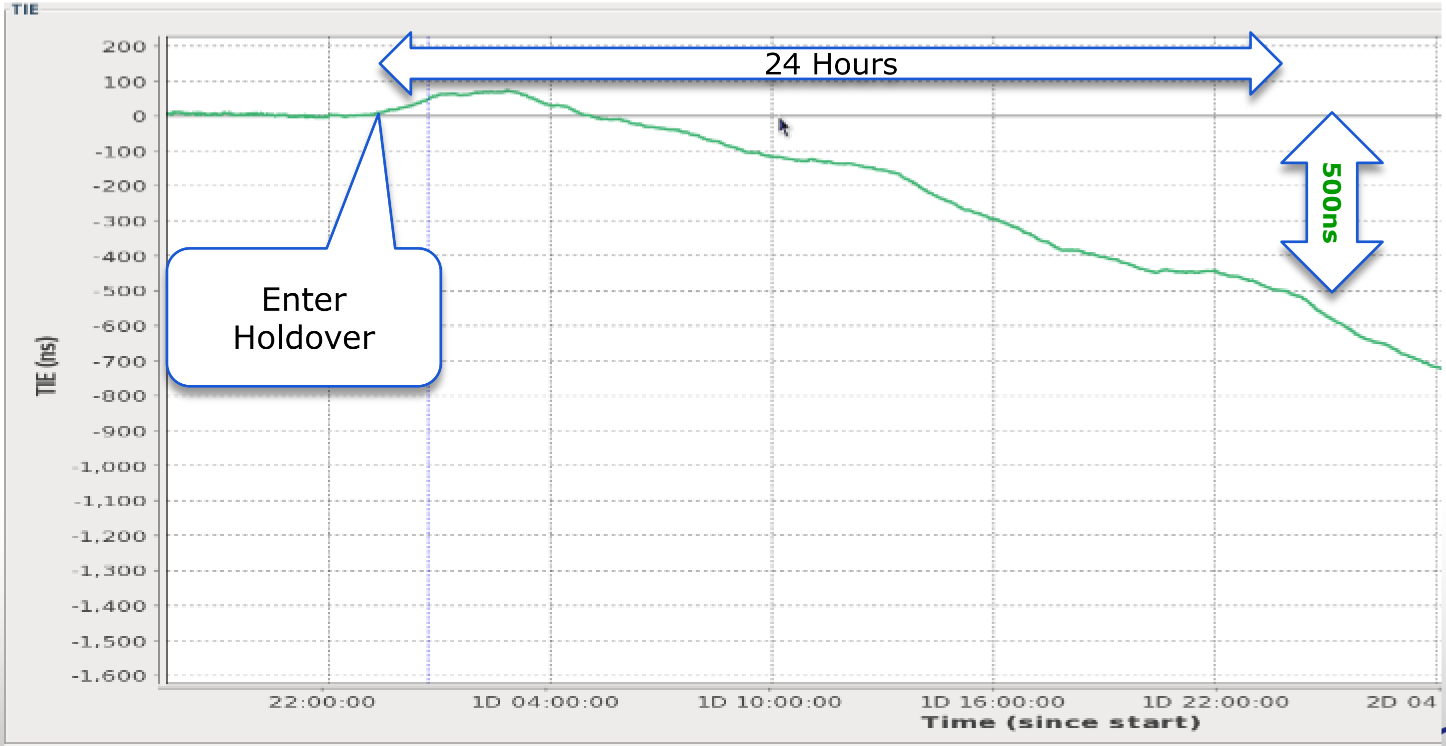
HQQ Holdover at +/- 20C (0-40C)

- Tested in the Oven with temperature profile +/- 20C
- Phase Holdover over 24 hours below 500nsec !



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Advantages of the High Quartz Oscillator Over Rubidium

- **Better operational temperature range and stability** – guarantee better performance in the field
- **Cost Effective Solution** – ~one third of the cost
- **Superior holdover performance** with the aging learning algorithm enabled for High quality oscillator

	400nsec	1.1usec	1.5usec	5usec	10usec
HQ Oscillator	15 hours	~1.3 days	2 days	4 days	6 days
Rubidium benchmark	NA	NA	1 day	3 days	5 days

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Thank You