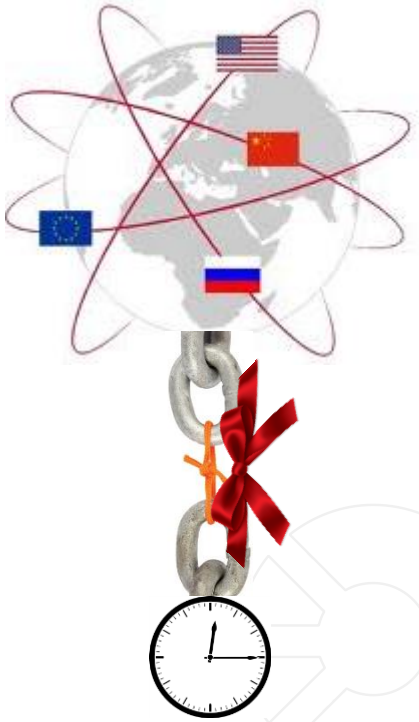
OSCILLOQUARTZ

An ADVA Optical Networking Company



Reducing time errors from GNSS - Time for multi-Band?

Kenneth Hann, Senior Director R&D , Oscilloquartz

WSTS March 2019

Motivation & Background

(for high accuracy time)

1. GNSS – easier timing deployment
   - 5G, small-cell … Power; Financial;…

2. GNSS – higher timing accuracy
   - Integrated-GM Measurement results

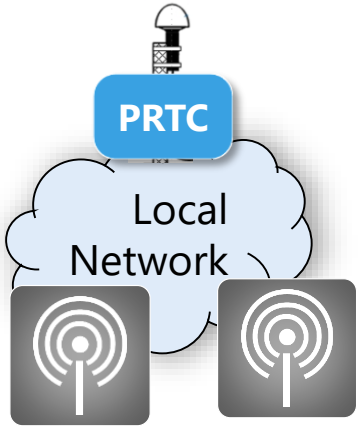
3. GNSS – improved timing resiliency
   - Backup and monitoring are essential

GNSS everywhere…

With the same challenges

GNSS is a critical component of (almost) all time systems

Remote Dependence



Local Dependence

Embedded
Dependence

OSCILLOQUARTZ
An ADVA Optical Networking Company

GNSS - enabler for fast Time rollout

Options:

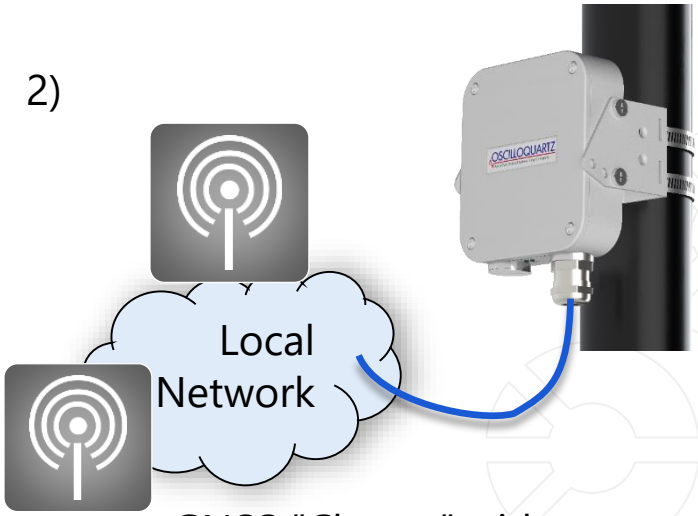
1)

GNSS Equipment Integrated

1b)

GNSS Integrated as SFP

2)



GNSS "Cluster" with integrated GM

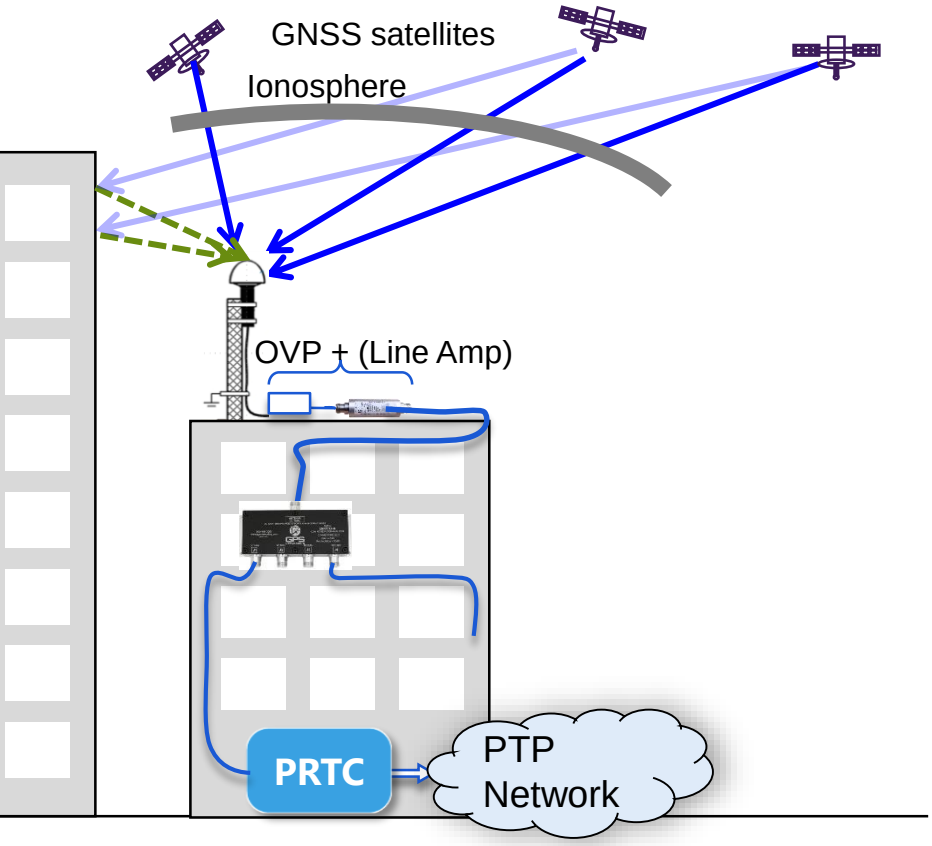
OSCILLOQUARTZ
An ADVA Optical Networking Company

Sources of GNSS time errors

	Magnitude	Mitigation
1) Antenna/cable delay (error)	?	Measure or Integrate
2) Multipath effects (deep urban canyon)	10-100ns	Design
3) Ionosphere variations	20 – 50ns	Multiband
4) Local interference (jamming)	?	Monitoring & Backup
5) Deliberate attack (spoofing)	?	Monitoring & Backup
6) GNSS antenna / receiver failure	?	Monitoring & Backup

Multiband Helps

PRTC time error with “traditional” system



Fixed Delays

- Antenna delay
- RF Line Amplifier delay
- RF cable(s) delay
- RF splitter delay
- Multi-path effects
- Ionosphere effects

Compensate delays for high time accuracy

Direct signal

Reflected signal

OSCILLOQUARTZ
An ADVA Optical Networking Company

1) Removing Antenna/cable delays

Integrated GrandMaster - with extras (APTS, monitoring…)

- Fast, Easy Installation
- Optimized for partial sky view
- Ethernet cabling Copper or Fibre

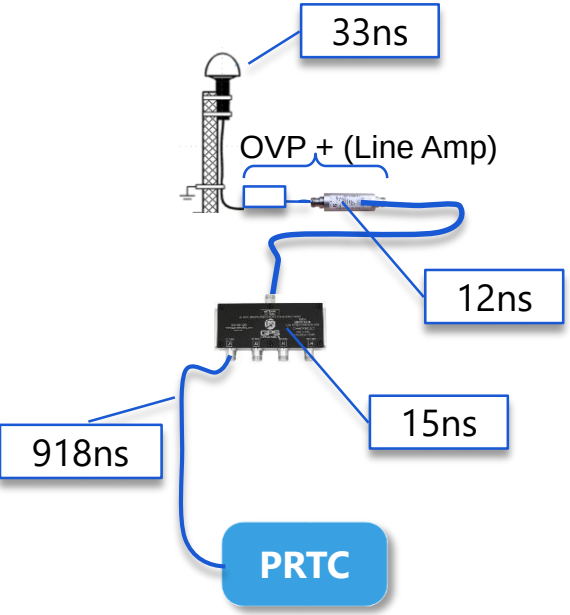
(No RF-cabling required)

Outdoor (Pole/wall)

Indoor (window)

OSCILLOQUARTZ
An ADVA Optical Networking Company

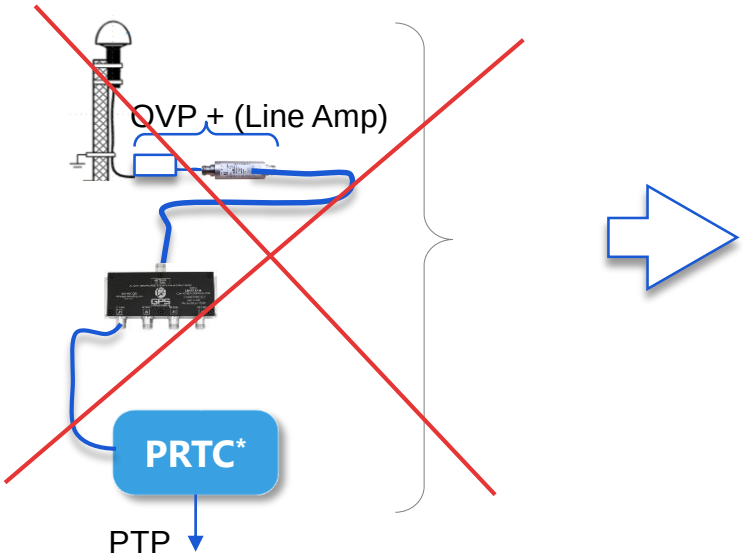
RF delays – site specific compensation



Antenna Vendor	Typical delay	Delay variation
A (commercial)	23nsec	+/-15
B (commercial)	19nsec	+/-10
C (high end)	10nsec	+/-5

Accurate compensation of RF delays is difficult!

Move to Integrated GrandMaster (and avoid the RF delay problem)



Outdoors

Indoors

IOT GM → UTC

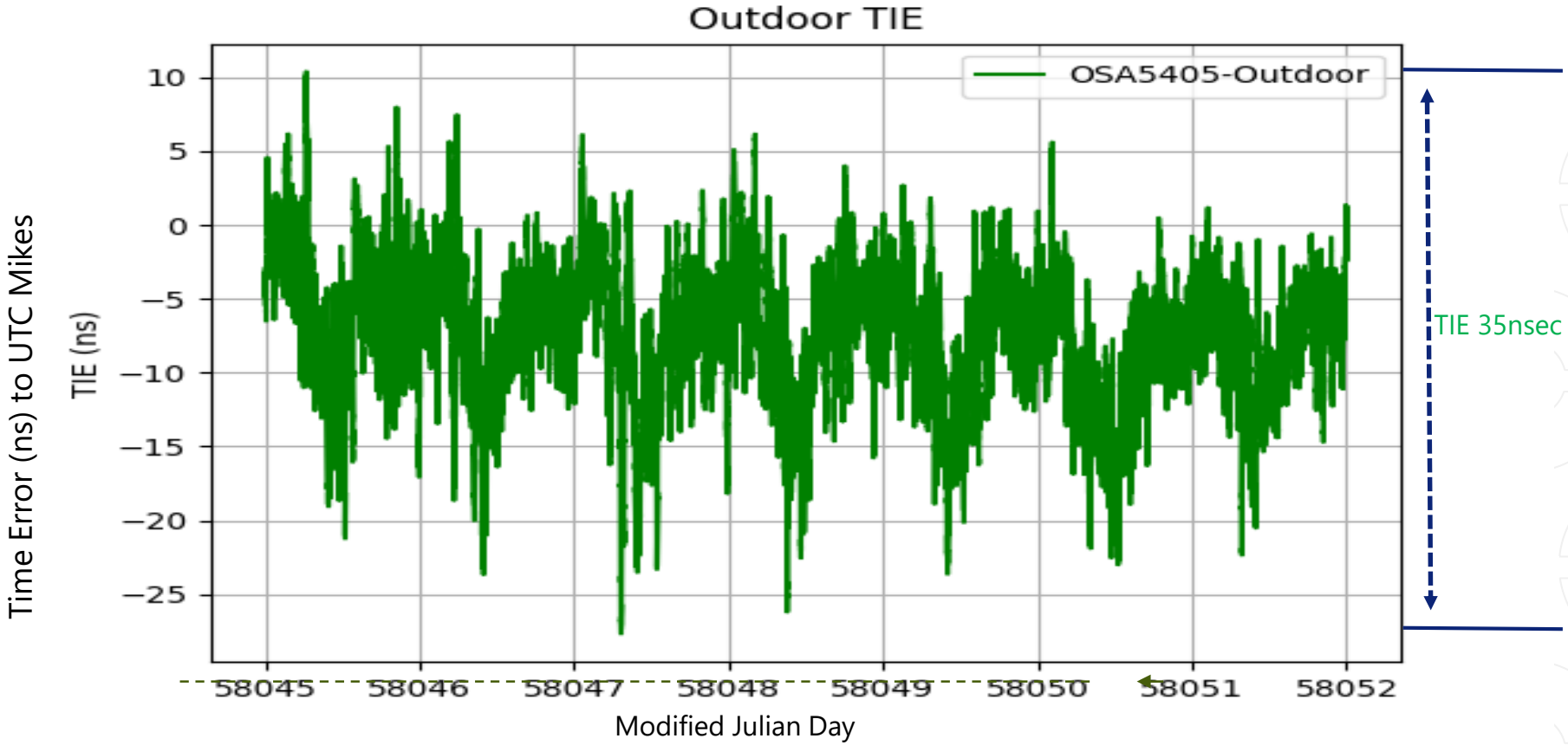
* PRTC includes GM function

OSCILLOQUARTZ
An ADVA Optical Networking Company

2) Design for minimal multipath

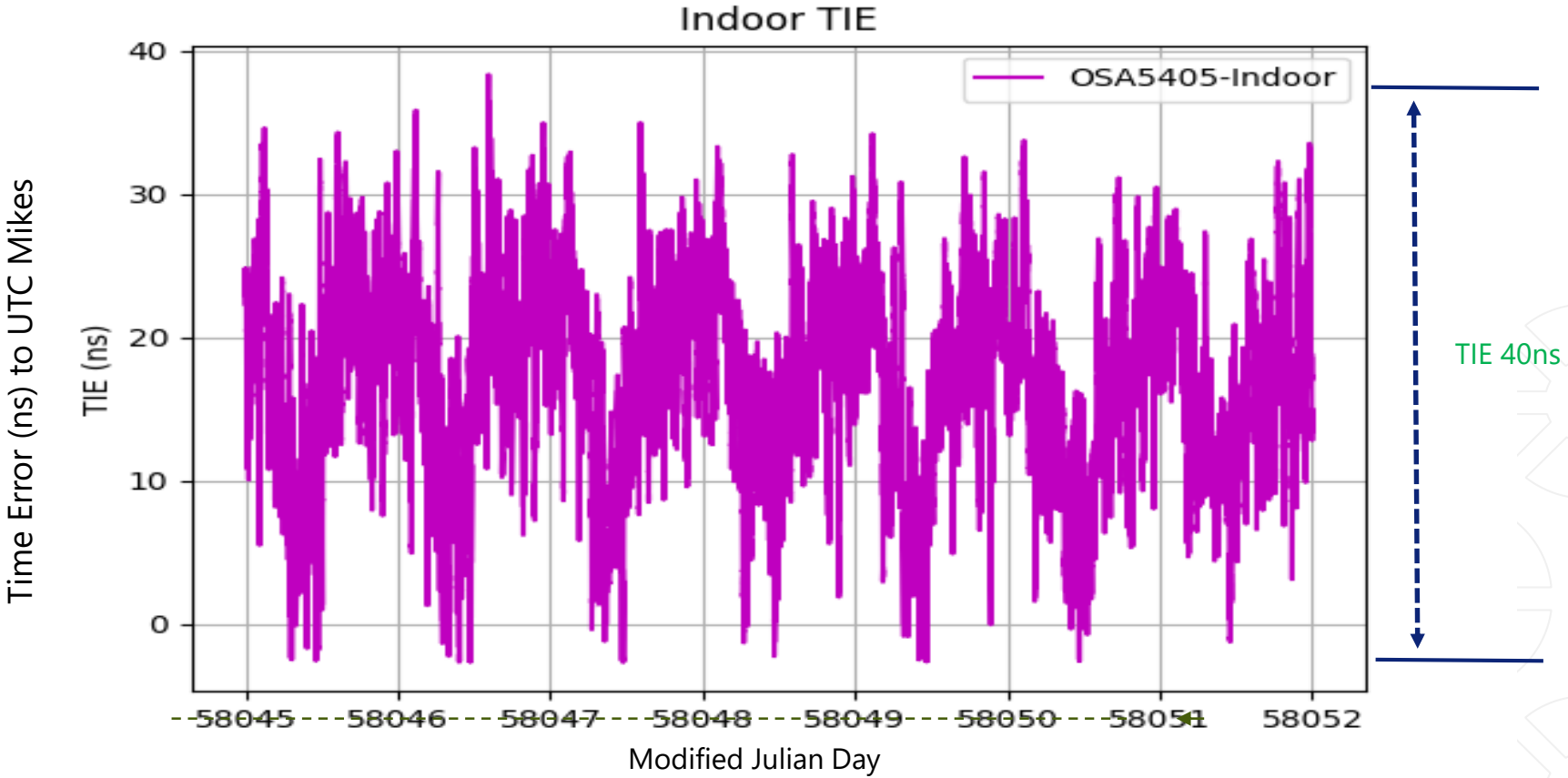
Testing at national lab (VTT MIKEs)
#1 Indoor (glass bricks); #2 Outdoor (wall)

Test results (~1 week) 5405 Outdoor

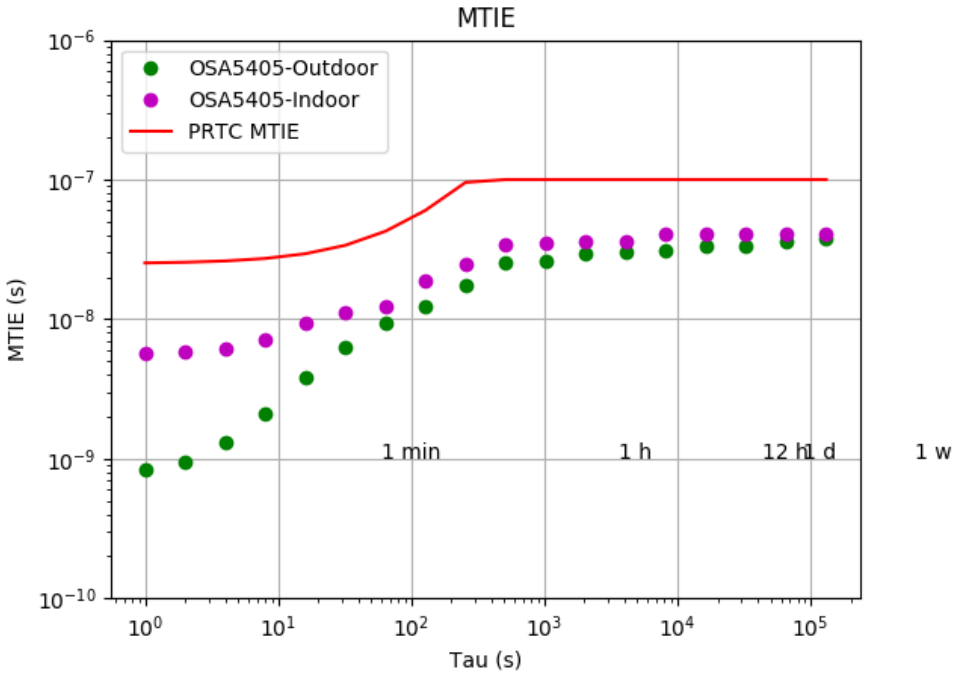


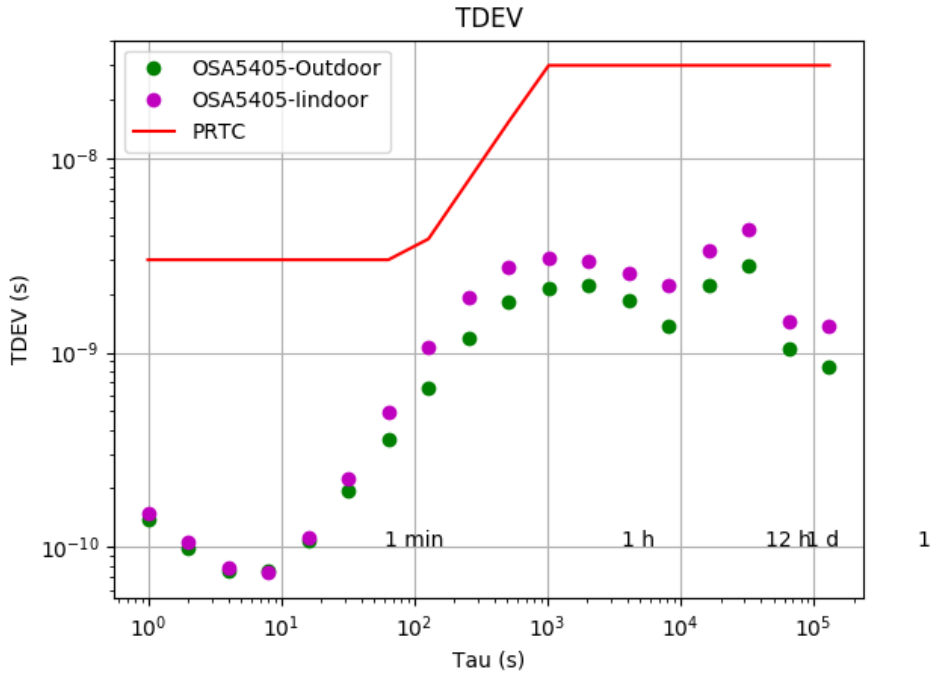
OSCILLOQUARTZ
An ADVA Optical Networking Company

VTT Test results (~1 week) 5405 Indoor



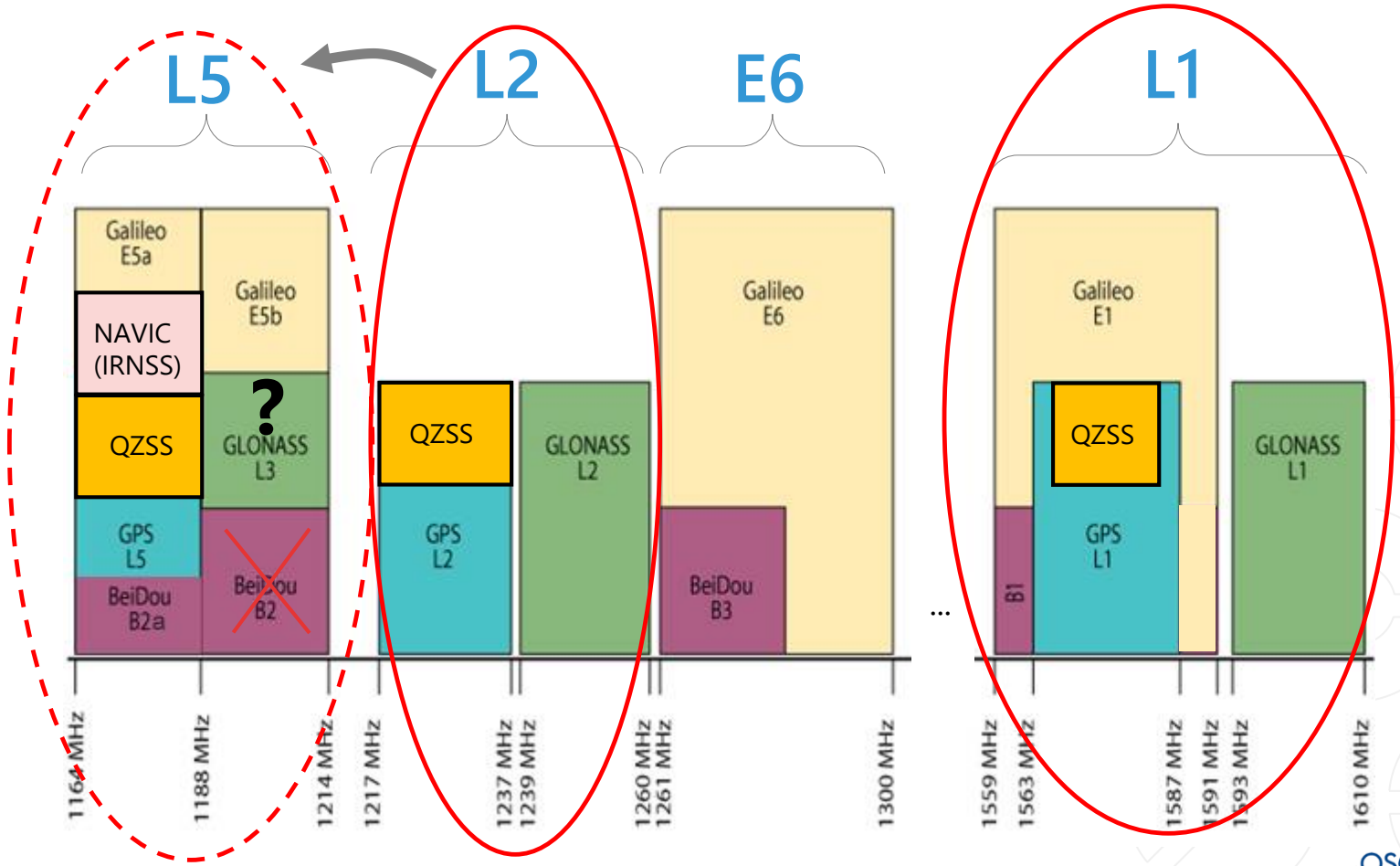
VTT Test results – MTIE / TDEV



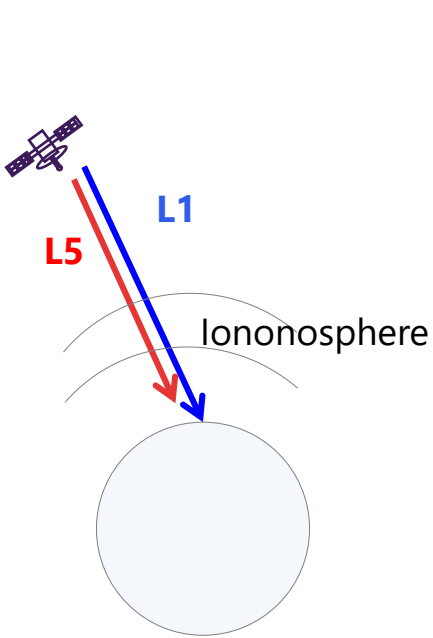


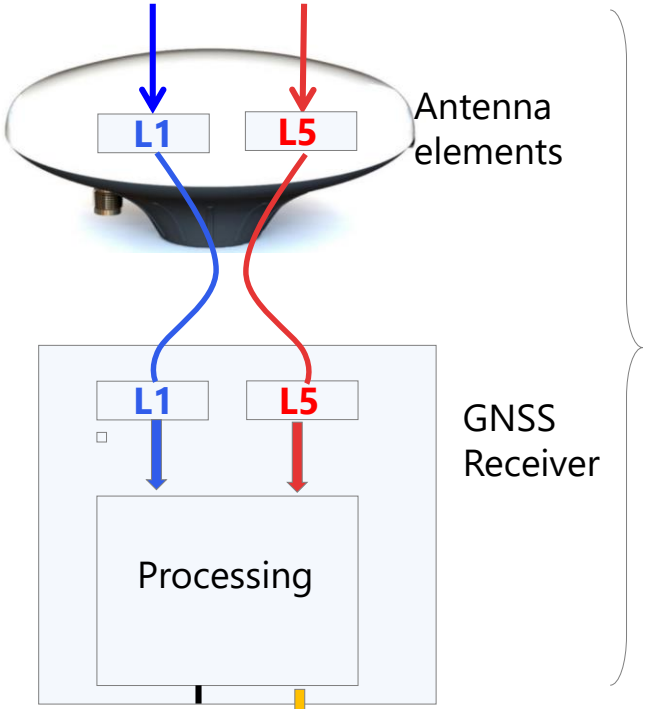
3) Ionosphere delay - the case for multiband

GNSS Multiband = L1 + ?

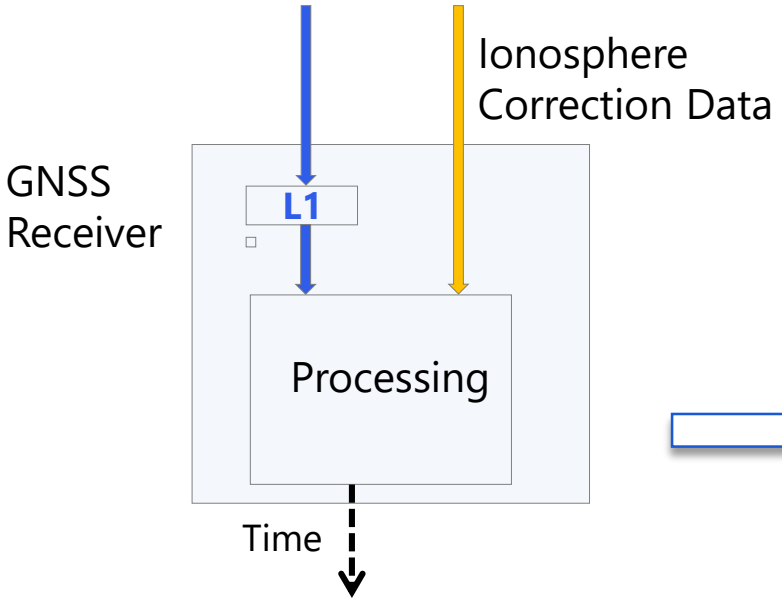


Ionospheric delay correction





Benefits of multi-band for L1 receivers



Ionospheric compensation:

1) Distribution via network

2) Distribution via SBAS L1 (or L5)

OSCILLOQUARTZ
An ADVA Optical Networking Company

Benefits of networking GNSS devices

Service management (Back-up and optimization)

Network management (monitors each clock)

Network >> sum of parts

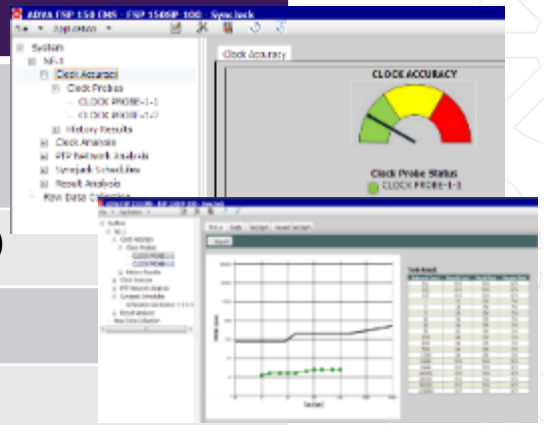
OSCILLOQUARTZ
An ADVA Optical Networking Company

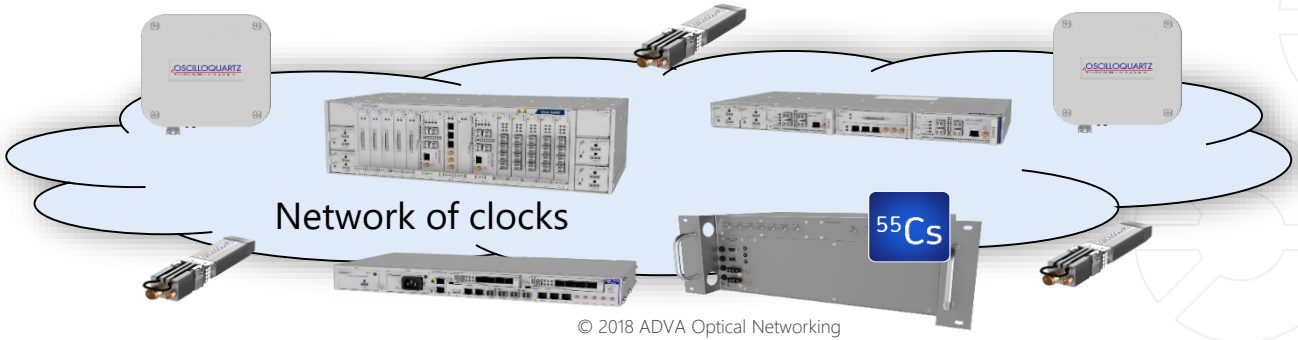
4) Synchronization service - Monitoring and backup

Essentials for robust time provisioning

2. Monitor and correlate Key Performance Indicators (KPIs)

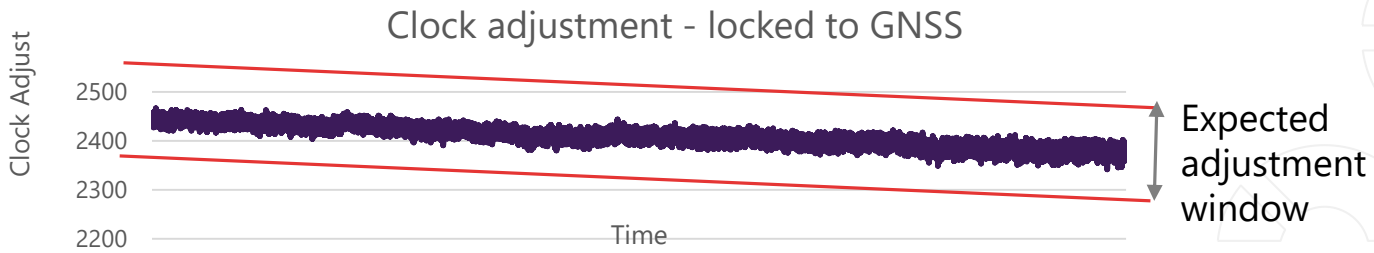
GM Monitoring	KPIs
GNSS data	#Carrier locked Satelites SNRs; AGC Jamming, Spoofing, warnings
GNSS V PTP	MTIE (after assymetry correction)
GNSS V SyncE	MTIE
GNSS V OCXO	Freq offset (ppb)





Correlate GNSS KPIs

KPI Monitoring (Location C)	Possible Events
GNSS V OCXO	Rapid adjustment
GNSS V Remote clock	MTIE outage
GNSS data	Suspected: Spoofing; Jamming; ...



Conclusions

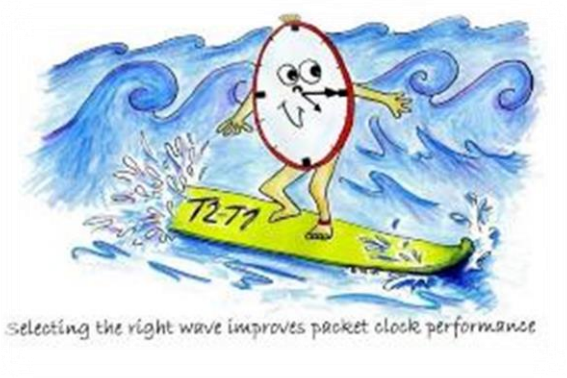
1) Compensation of unknown delays is key to accuracy

- "Cable" delays – avoid with Ethernet cabling
- Ionospheric delays – use multiband receiver or
- (L1 receivers compensate via SBAS or Network)

2) Use the network for making timing services

- Monitor and correlate KPIs

Thank You



OSCILLOQUARTZ
An ADVA Optical Networking Company

Thank you

Testing at VTT MIKES

- VTT provides UTC MIKES
- Distance 876m
- Fibre connection
- PTP White Rabbit
- Accuracy UTC ~5ns

Link to Finnish Time keeper VTT MIKES

Improvements to GNSS technology

Encrypted L2 GNSS receivers

CRPA antennas

Multiple GNSS constellations

Military / Government

Cost

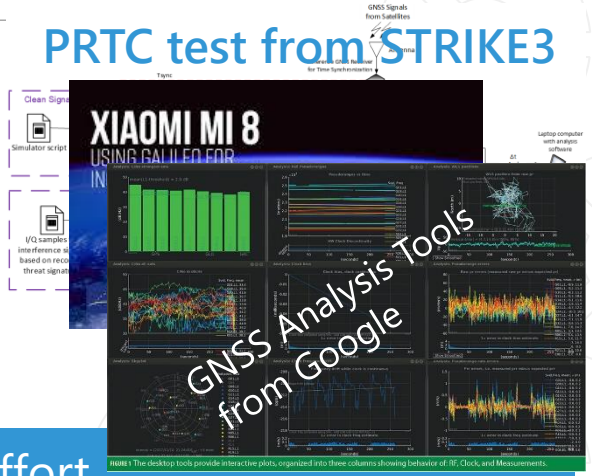
Challenges

GNSS L1 receiver certification (STRIKE-3)

Multiple Band GNSS receivers (e.g. L1 + L2 /L5)

Google – Raw data + analysis tools

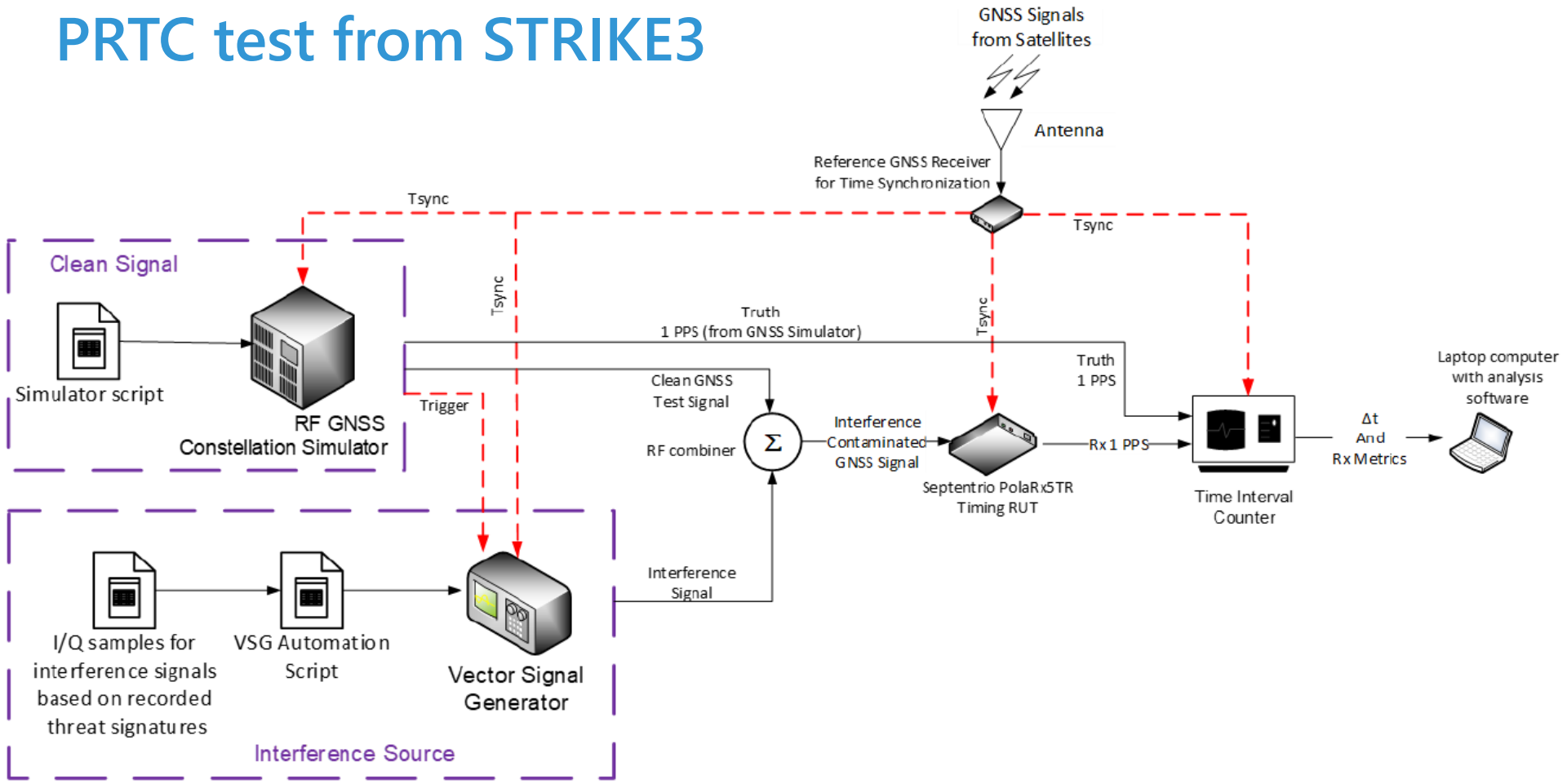
PRTC test from STRIKE3



Civilian GNSS service remains best effort

OSCILLOQUARTZ
An ADVA Optical Networking Company

PRTC test from STRIKE3



OSCILLOQUARTZ
An ADVA Optical Networking Company

STRIKE3 – One effort to document and categorize GNSS threats.

Standardisation of GNSS Threat reporting and Receiver testing through International Knowledge Exchange, Experimentation and Exploitation

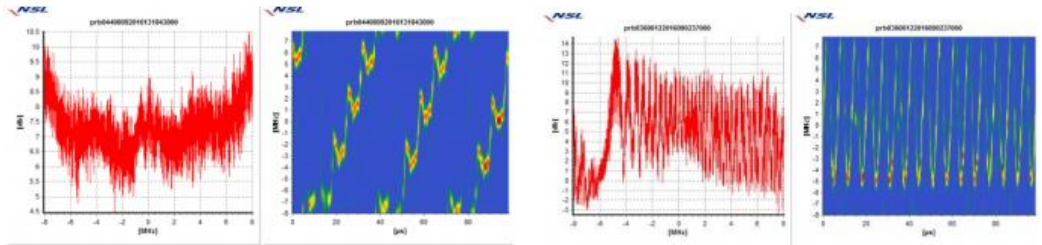
Funded by EU-H2020 programme (Galileo)

Fingerprinting jamming techniques focusing on the RF waveform

Field recording-> Lab analysis -> Test playback

D4.2 Draft standard for receiver testing against threats

- considers jamming interference only in GPS L1 / Galileo E1

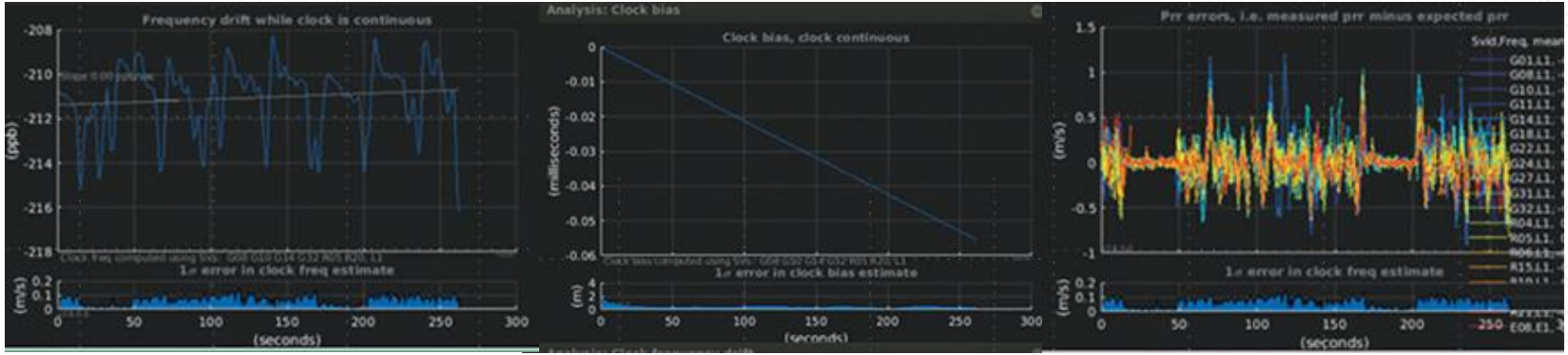


http://www.gnss-strike3.eu/

OSCILLOQUARTZ
An ADVA Optical Networking Company

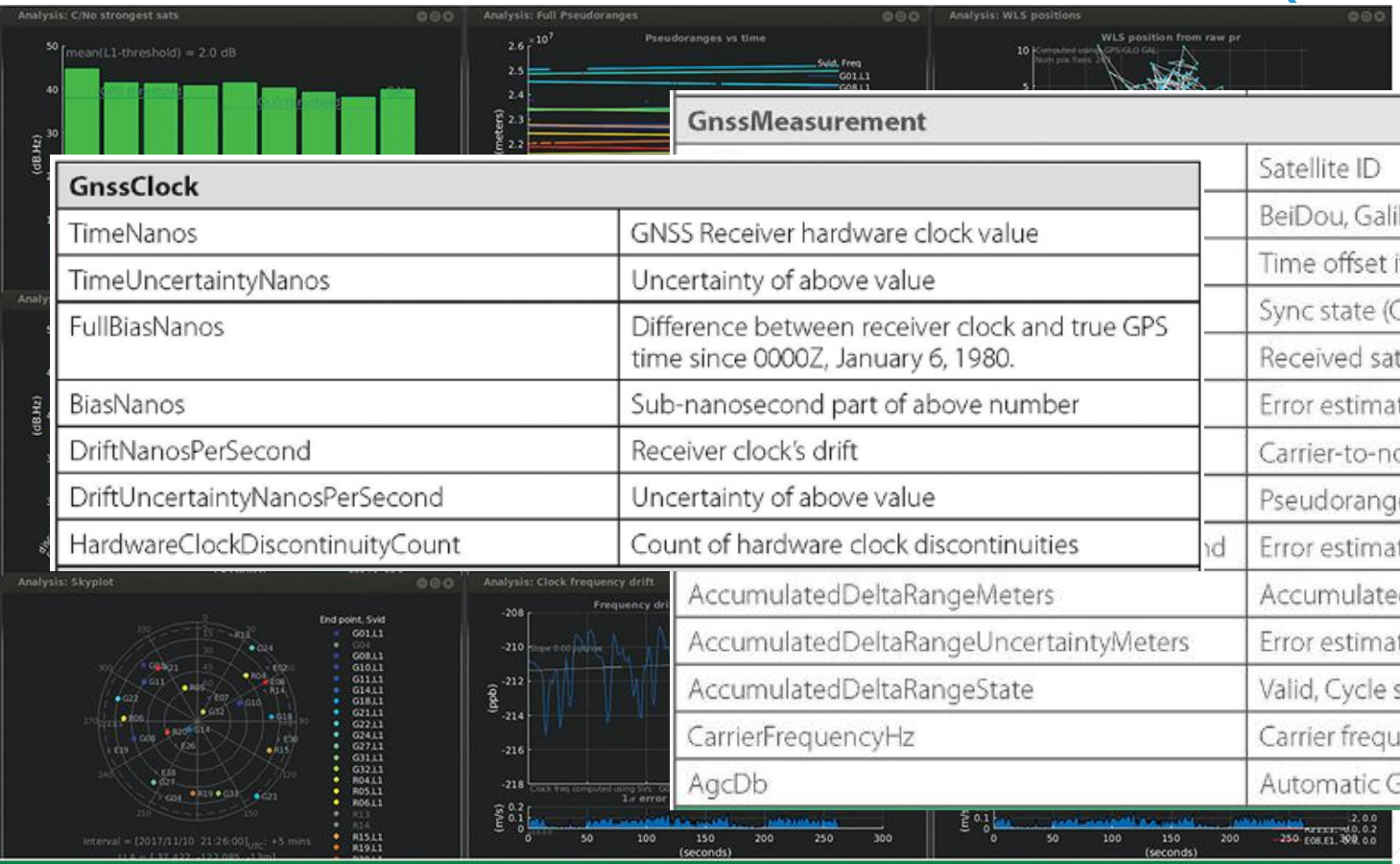
Data available from GNSS receivers?

1. Google released GNSS raw data on Android. Also GNSS Analysis Tools to process and analyze raw data.
2. Raw measurement data shows the receiver clock to better than 1ppb precision.
3. Raw data allows insight into the signal environment and receiver behaviour
4. Chipset vendors provide API, but raw GNSS data ?



http://insidegnss.com/gnss-analysis-tools-from-google/

Some of the Raw attributes available (Google GNSS)



GnssClock	
TimeNanos	GNSS Receiver hardware clock value
TimeUncertaintyNanos	Uncertainty of above value
FullBiasNanos	Difference between receiver clock and true GPS time since 0000Z, January 6, 1980.
BiasNanos	Sub-nanosecond part of above number
DriftNanosPerSecond	Receiver clock's drift
DriftUncertaintyNanosPerSecond	Uncertainty of above value
HardwareClockDiscontinuityCount	Count of hardware clock discontinuities

GnssMeasurement	
	Satellite ID
	BeiDou, Galileo, GLONASS, GPS, QZSS, SBAS
	Time offset if measurements are asynchronous
	Sync state (Code lock, bit sync, frame sync, etc.)
	Received satellite time, at the measurement time
	Error estimate of above value
	Carrier-to-noise density ratio
	Pseudorange rate (-Doppler)
	Error estimate of above value
AccumulatedDeltaRangeMeters	Accumulated delta range (carrier phase)
AccumulatedDeltaRangeUncertaintyMeters	Error estimate of above value
AccumulatedDeltaRangeState	Valid, Cycle slip or Loss-of-lock/Reset
CarrierFrequencyHz	Carrier frequency of the tracked signal
AgcDb	Automatic Gain Control level

FIGURE 1 The desktop tools provide interactive plots, organized into three columns showing behavior of: RF, Clock, and Measurements.

OSCILLOQUARTZ
An ADVA Optical Networking Company