OPNT Technical Report + Test Plan v1.6

Alternative Position, Navigation and Timing (PNT) Services
DEFIS/2020/OP/0007
D210

Revision history

Version	*Date*	*Author*	*Remarks*
0.1	27 July 2021	N. Coesel	Initial draft version
0.4	20 Sept 2021	N. Coesel	- Text changes - Updated table numbering - Added section on availability - Updated performance tables - Added headers to test cases outlining purpose and outcome of tests - Split radio link (RSTU) and fiber (White Rabbit) tests - Added GPSDO and GPS antenna to equipment list. - Added T4E test case
0.5	22 Oct. 2021	N. Coesel	- Added fault conditions + remedies
1.0	26 Oct. 2021	N. Coesel	- Final modifications (document number)
1.1	10 Dec. 2021	N. Coesel	- Updated test cases with actual values used - Added test results & graphs
1.2	23 Dec. 2021	N. Coesel	- Added table of contents
1.3	13 Jan. 2022	N. Coesel	- Added / expanded T4E RSTU demo
1.5	17 Feb. 2022	N. Coesel	- Added test results for T4E RSTU demo
1.6	28 Feb. 2022	N. Coesel	- Updated graphs - Added actual runtimes to the test results - Added real world implementation

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Technical description

The OPNT time and frequency distribution system can provide Europe-wide timing by leveraging existing telecommunication fiber networks to connect multiple National Metrology Institutes (NMIs) to a stationary user. The European NMIs are responsible for producing the legal European UTC time. NMI sources can include any European Time and Frequency Laboratory that allow the connection of OPNT equipment to their timing source. OPNT will provide this service under its Timing as a Service (TaaS) offering. OPNT's offerings are focused on Timing, the "T" in PNT.

OPNT's offering is a terrestrial-based global Timing system designed with the capability of outperforming GNSS Timing. The core concept makes use of the existing fiber-based telecom infrastructure to connect to National Metrology Institutes and transforms the fiber network into the equivalent of a fully distributed and highly redundant UTC-synchronized atomic clock, resulting in a very cost efficient, wide area timing solution with accuracy levels ranging from milliseconds down to hundreds of picoseconds, based on user accuracy requirements.

In addition to the delivery of wireline-based timing in standardized formats that users are accustomed to (e.g.1PPS, PTPv2, and NTP), OPNT can also incorporate the use of fiber-based time in support of wireless-based time dissemination. Furthermore, OPNT can use the fiber-based time capability to monitor the time distribution within multiple wireless transmission systems, including GNSS and mobile networks. Building on top of this wireless monitoring capability is the ability to provide corrections in real-time to existing wireless infrastructures, like mobile networks, to keep them synchronized to the same source.

Performance parameters fiber link

Performance Parameter (X days after GNSS outage)	1 day	14 days	100 days
Horizontal Accuracy (95%) m	na	na	na
Vertical Accuracy (95%) m	na	na	na
Availability (%) [1]	100%	100%	99.9999% [5]
Continuity (per hour)	100%	100%	99.9999%
Integrity (per hour)	100%	100%	99.9999%
Time To Alarm (second)	1	1	1
Timing Accuracy to UTC (3sigma) [2]	+/-0.1ns	+/-0.1ns	+/-0.1ns
Within a metro	+/-0.5ns*	+/-0.5ns*	+/-0.5ns*
< 250 km	+/-1ns*	+/-1ns*	+/-1ns*
250 – 1000 km	+/-2.5ns*	+/-2.5ns*	+/-2.5ns*
EU Wide	+/-5ns*	+/-5ns*	+/-5ns*
Time synchronization (Allan Deviation / 3 sigma) [3]	TBD	TBD	TBD
Timing Stability (Allan Deviation) [3]	TBD	TBD	TBD
First time to provide services upon cold start-up (including system and receiver contributions) [4]	20m	20m	20m

Table 1: Performance Levels of the alternative PNT service

*performance parameters based on White Rabbit (Ultra-high precision) implementation
1) Under the assumption OPNT's solution is deployed fully redundant.
2) With respect to the time provided by the NMI(s) serving as a time source and assuming OPNT's equipment is installed at the NMI with a direct connection to the atomic clock ensemble.
3) Not applicable since there is no hold-over oscillator involved in OPNT's solution.
4) Worst case scenario
5) Number obtained from links which OPNT has deployed already

Performance parameters RSTU

Performance Parameter (X days after GNSS outage)	1 day	14 days	100 days
Horizontal Accuracy (95%) m	na	na	na
Vertical Accuracy (95%) m	na	na	na
Availability (%) [1]	100%	100%	99.9999% [5]
Continuity (per hour)	100%	100%	99.9999%
Integrity (per hour)	100%	100%	99.9999%
Time To Alarm (second)	10	10	10
Timing Accuracy to UTC (3sigma) [2]			
Within a metro	+/- 200ns	+/- 200ns	+/- 200ns
< 250 km	na	na	na
250 – 1000 km	na	na	na
EU Wide	na	na	na
Time synchronization (Allan Deviation / 3 sigma) [3]	TBD	TBD	TBD
Timing Stability (Allan Deviation) [3]	TBD	TBD	TBD
First time to provide services upon cold start-up (including system and receiver contributions) [4]	20m	20m	20m

Table 2: Performance Levels of the alternative PNT service

*performance parameters based on White Rabbit (Ultra-high precision) implementation
1) Under the assumption OPNT's solution is deployed fully redundant.
2) With respect to the initial offset of the corrected timing switch.
3) Not applicable since there is no hold-over oscillator involved in OPNT's solution.
4) Worst case scenario
5) Number obtained from links which OPNT has deployed already

Continuity

Continuity and integrity are ensured by using a system which has multiple geographically diverse timing input sources used in a fully redundant setup. The system will be constantly monitoring each timing input, discard and notify on any compromised timing source by doing majority voting (based on pre-defined priorities) through OPNT's Timing Analysis and Selection Engine (TASE).

The target MTBF for the equipment is 90 000 hours (excluding fans). The MTTR (Mean Time To Repair) depends on SLA and presence of maintenance staff and spare equipment on-site. In the best case scenario (with people and spare units on-site), a device can be replaced & configured within 30 minutes.

The table below lists possible fault scenarios and how the system deals with those:

Fault	**Reaction**
Fiber break	A redundant link takes over and an alarm is raised.
Equipment failure	A redundant device will take over and an alarm is raised
Timing source failure or tampering	A secondary time source will used and an alarm is raised

Test Plan

OPNT proposed tests

Demonstration activities

OPNT will demonstrate the following capabilities:

1. Sub-nanosecond time synchronization between source and destination over short and long fiber links, where the long link uses a repeater to amplify the optical signal during nominal operations.
2. Redundancy for achieving high availability with well-defined behavior under fault conditions. The proposed fault conditions will simulate fiber breaks and compromised timing sources.
3. Tracking and correcting time offsets between a wireless transmitter and receiver (the test uses a wired connection between receiver and transmitter simulating the wireless part in order to avoid RF interference and licensing issues).

Proposed approach

The following tests will be performed:

- System verification test (initial system bring-up and nominal operation)
- Frequency transfer test
- Time transfer test
- Link interrupt test to show resilience against link interruptions
- Clock wander test to show resilience against clock degradation

All the OPNT proposed tests will take place indoors. This set of tests has already been successfully demonstrated in the US Department of Transportation GPS Backup Trial. Technically it would be possible to perform tests stationary in the field (outside) but this does not provide any extra relevant data. If useful and permitted, OPNT can make use of JRC Ispra fiber infrastructure to distribute timing and frequency to other site locations.

Test setup

Equipment list

Name	*Provided by*	*Description*
TS10 (5x)	OPNT	OPNT's proprietary White Rabbit capable timing switch. 
Repeater (1x)	OPNT	OPNT's Repeater 
50km Fiber spool (2x)	OPNT	50km fiber spool to act as a long link
Various	OPNT	SFPs, fibers patches, mains cords, T pieces, etc to connect the various devices in the test setup
PC1+SDR (Small Cell Simulator)	OPNT	PC and SDR unit to drive the test transmitter for RSTU by simulating a small cell tower. The PC also has an NTP server.
PC2+SDR (RSTU)	OPNT	PC and SDR unit which runs the RSTU software
GPSDO	OPNT	GPS disciplined oscillator for use during T4
Wideband antennas	OPNT	
Laptop	OPNT	Computer to configure and monitor the test setup.
Cabinet (2x)	OPNT	Small table top 19" rack to mount the equipment in.
Time source	JRC Ispra	Time source + distribution system. At least 3x 1PPS and 3x 10MHz outputs that can be assigned to OPNT are required.
Time interval & frequency counter	JRC Ispra	Time interval counter or other device to monitor time stability from 1PPS outputs. This device should have a resolution of 50ps or better and referenced to the time source.

GPS Antenna	OPNT	
Roof space	JRC Ispra	Roof space for GPS antenna or GPS antenna signal
TIC (1x)	OPNT	Used by OPNT for installation and troubleshooting
Oscilloscope	OPNT	Used by OPNT for installation and troubleshooting
VPN Switch	OPNT	Used for remote monitoring and management. Uses OpenVPN connection on port 1194 for both TCP and UDP
Ethernet switch	OPNT	Network switch to establish management network
Internet Access	OPNT/JRC Ispra	Used for remote monitoring and management.
SMC to SMA cables	OPNT	OPNT will provide SMC to SMA (plug) cables for use during the test
SMA to BNC adapters	OPNT	OPNT will provide SMA to BNC adapters for use during the test

OPNT TS10

The TS10 is a Timing Switch which supports White Rabbit, PtPv2, NTP and NMEA (using GPZDA or GPRMC message formats) time protocols, including redundancy and TASE capabilities. This switch has been designed to be NEBS compliant telecom grade equipment. This is a 1U 19” rackmount unit.

OPNT Repeater

The Repeater is a device used for the optical signal amplification. In very long links multiple repeaters can be cascaded. This is a 1U 19” rackmount unit.

OPNT RSTU

The RSTU (Radio Signal Timestamping Unit) consists of a rack mountable PC and an SDR (software defined radio) unit. The RSTU compares the trusted time source with the received signal. Currently the RSTU supports LTE signals only.

OPNT Navigator

Software tool used for monitoring OPNT devices and services.

Small Cell Simulator

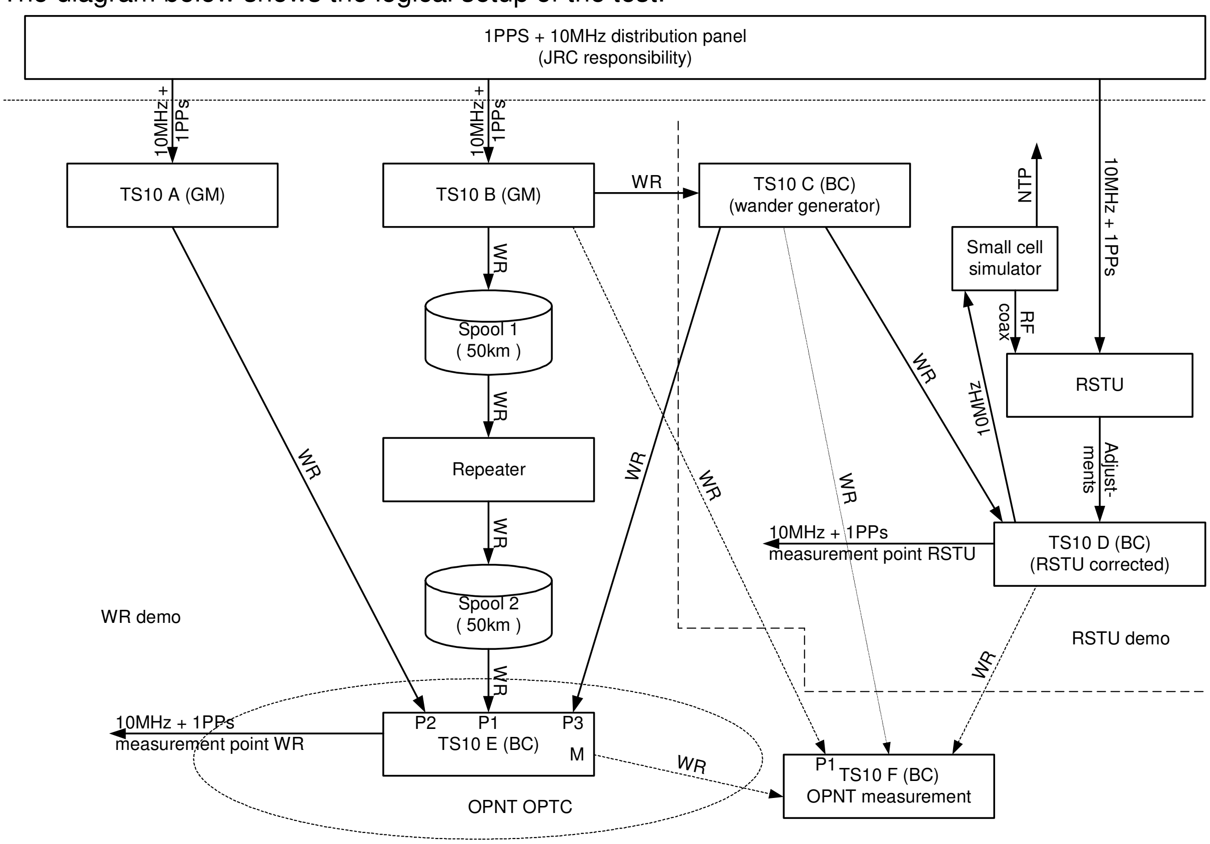
The Small Cell Simulator consists of a rack mountable PC and an SDR unit. The purpose is to simulate a standard cell tower. The Small Cell Simulator is synchronized with a Timing Switch which can create an offset in respect to the time source in order to simulate a cell tower with a drifting time source.
For simplicity reasons the PC driving the small cell simulator also provides an NTP server to the GW switches so they are set to the same time.

JRC Ispra time source

The JRC Ispra time source provides at least 1PPS and 10MHz to the system. At least three outputs (3x 10MHz and 3x 1PPS) will be needed. 10MHz: sine >=7dBm or square wave >=3.3V, 1PPS: TTL levels 3.3V or 5V.

Test setup description

The diagram below shows the logical setup of the test:



The test setup is split into two parts:

- WR (White Rabbit) demonstration
- RSTU demonstration

Notes:

- TS10 C is used by both tests (WR and RSTU).
- TS10 E can be considered the point where the end user is connected to
- TS10 F is not part of the test setup but used by OPNT to measure the time offsets and collect data. It acts as a (high precision) multi-port TIC.

White Rabbit demonstration

The White Rabbit demonstration is centered around TS10 E. This receives 2 links from 2 GMs (TS10 A and TS10 B) and 1 link from TS10 C. The link from TS10 B has a total length of 100km and also has a repeater in between. The fiber spools and repeater are a representation of a real world field deployment.
TS10 C is running a special firmware edition which can introduce an artificial phase wander in order to simulate a clock which is drifting (+/-500ns using a triangle shape). The TASE engine which is part of the TS10 software in TS10 E will detect this drift and not consider the link from TS10 C as a valid clock source. The output from TS10 E will stay well within +/-1ns compared to the primary clock.

RSTU demonstration

The RSTU is demonstrated in an close-loop scenario in order to show it's phase correction ability. TS10 C feeds the small cell simulator with a drifting 10MHz + 1PPS. In turn this means the transmitted signal will also show a phase drift. TS10 D is fed from TS10 C using a White Rabbit link which is also drifting. The RSTU is synchronized to the primary clock and thus will measure the phase offset between the received signal and the primary clock. The measured offset is fed into TS10 D in order to counteract the drift generated by TS10 C. The result is that despite the +/-500ns drift from TS10 C, the output from TS10 D stays within +/-100ns in respect to the clock source.

Monitoring

OPNT has developed a Network Management System (NMS) tool called the OPNT Navigator that can monitor the status of the devices, receive alarms and generate performance graphs, notifications and daily performance reports. For the proposed tests a laptop will be used on site to demonstrate the remote management capabilities.
The OPNT Navigator will poll the monitored devices for status information at configurable time intervals using the SNMPv3 protocol with authentication and encryption enabled. The OPNT Navigator will also receive the SNMPv3 alarms sent by the OPNT devices, displaying the total received alarms, the active alarms and the device status in its dashboard. Optionally, received alarms can be forwarded to configured email addresses. The OPNT Navigator can run on any Linux distribution (tested so far only on Debian and Ubuntu distributions), on a local computer or in the cloud.
Alternatively, an SSH session can be open to an individual device for status and performance checking.

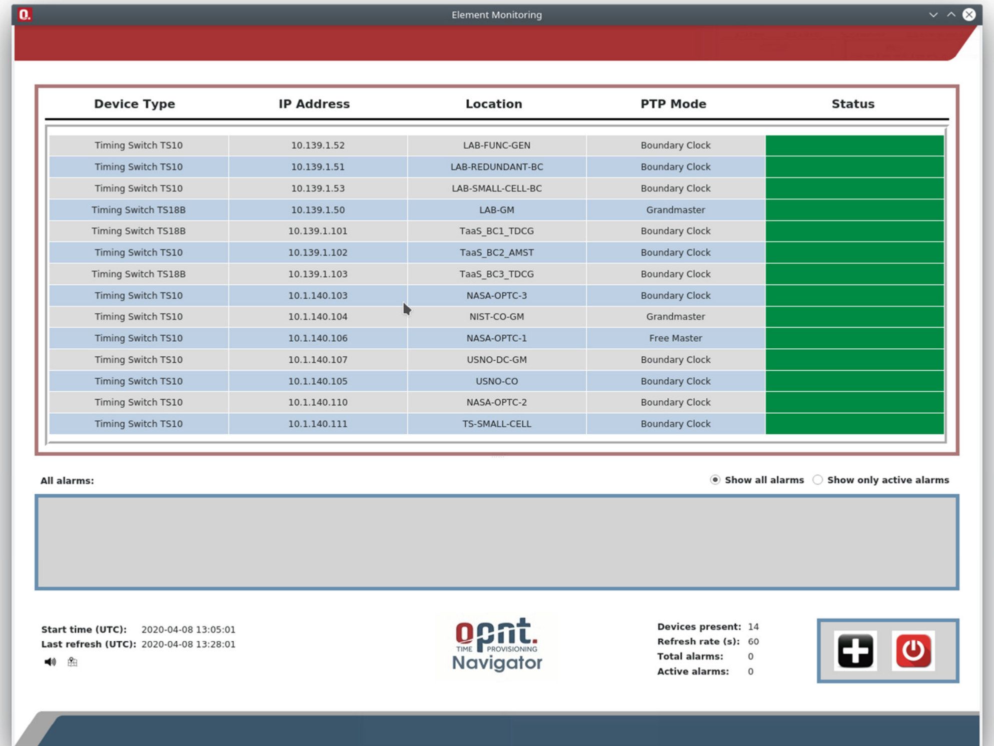


Figure 7: OPNT Navigator Network Element Monitoring

Test scenarios

T1D: System verification test (initial bring-up and normal operation)

Objective	The system verification test aims to verify the system has started properly and enters into a stable condition.
Output	Test setup ready to go
Time to execute	1 work day
Metrics	pass / fail

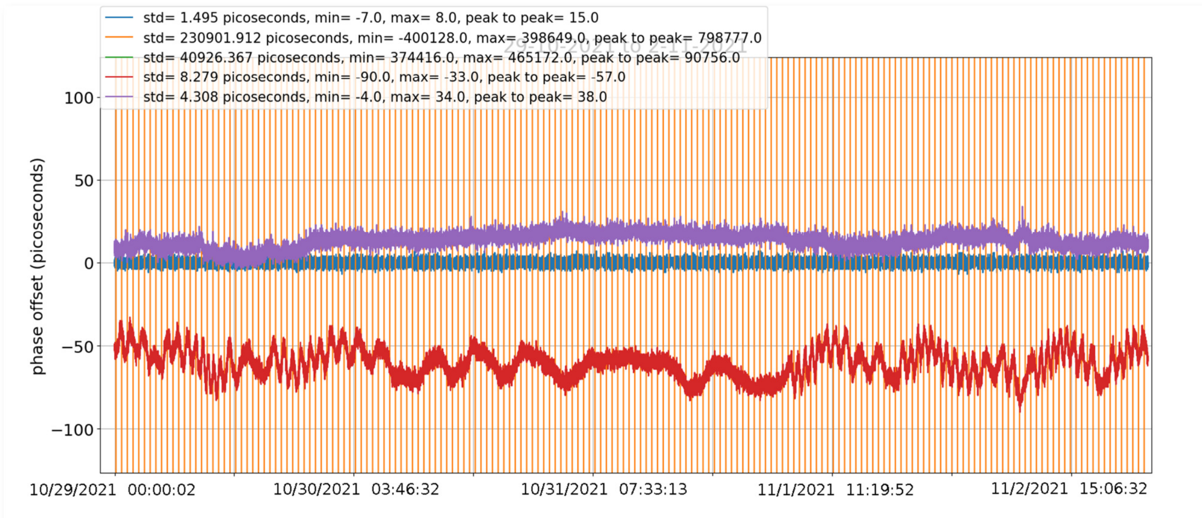
#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Verify configuration	Configuration OK		y
2	Power the system	Power leds & fans on		y
3	Check TS10 A and TS10 B lock to time source.	Status LED green		y
4	Check White Rabbit link status on TS10 C, TS10 D and TS10 E.	All WR links go to track phase (synchronized) state, offsets throughout the system are < 1 ns		y
5	RSTU synchronized to the time source?	Status : synchronized		y
6	Small Cell Simulator synchronized to the time from TS10 C?	Status: synchronized		y
7	RSTU can receive the Small Cell Simulator?	Status: reception OK		y
8	Check 1PPS delays between TS10 A and TS10 B using a time interval counter. The delay should be below 1ns. If not, then adjust the 1PPS input shift to compensate for the cable delay	Delay between 1PPS outputs below 1ns		y
9	Note offset between TS10 D (RSTU corrected) and 1PPS from TS10 B.	The corrections from the RSTU are relative so this offset will be the origin for the RSTU test results.	Offset: 400ns	y

Overall result: passed

T2J: Fiber link frequency stability test

Objective	The frequency stability tests measures between the clock source and the 10MHz output from TS10 E (White Rabbit time transfer)
Output	Frequency stability data for White Rabbit (fiber link)
Time to execute	Setup: 3 hours? (JRC connections), runtime: 72 hours
Metrics	quantitative, AVAR, MTIE versus reference clock
Notes	Run in parallel with test T2K

#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Check TS10 A and TS10 B are locked to the clock source.	TS10 A and TS 10B locked to external reference and their time is identical.		y
2	Check WR link status on TS10 C, TS10 D and TS10 E.	All WR links go to track phase (synchronized) state, offsets throughout the system are < 1 ns.		y
3	Verify status on OPNT Navigator and start collecting data from TS10 F	OPNT Navigator is collecting data from TS10 F		y
4	Check if the frequency measurement devices shows valid results for a period of 10 minutes.	People from JRC confirm that the frequency stability measurement device is taking proper measurements from TS10 E		y
5	Run the test for 24 hours			y
6	Post process data and verify results between OPNT Navigator and JRC measurements	Measurements agree TS10 E stays within +/-1 ns compared to the clock source		y



The graph and numerical analysis above shows that TS10E (red line) stays within +/- 1ns in respect to the reference (TS10B; dark blue line). The purple line shows the offset of TS10A.

Legend

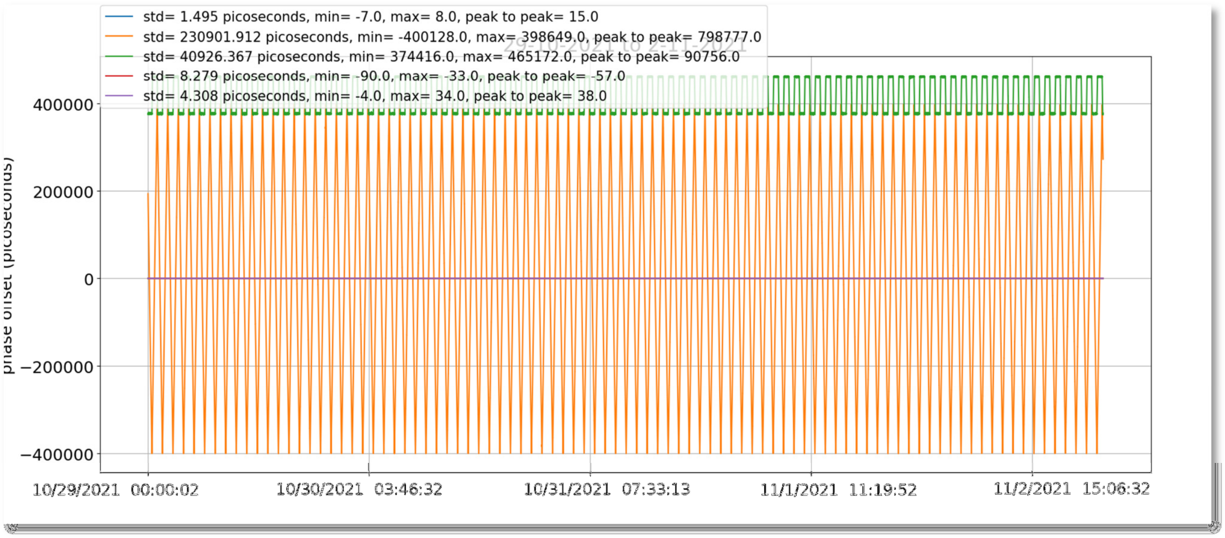
- TS10 A
- TS10 B
- TS10 C
- TS10 D
- TS10 E

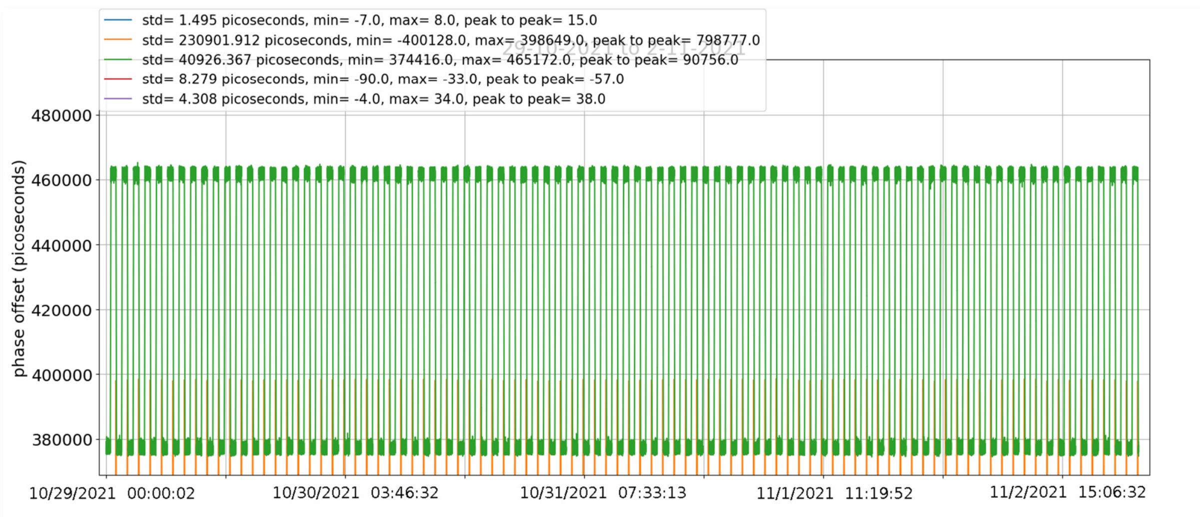
Overall result: passed

T2K: RSTU (radio link) frequency stability test

Objective	The frequency stability tests measures between the clock source and the 10MHz output from TS10D (RSTU time transfer)
Output	Frequency stability data for RSTU (radio link)
Time to execute	Setup: 3 hours? (JRC connections), runtime: 72 hours
Metrics	quantitative, AVAR, MTIE versus reference clock
Notes	Run in parallel with test T2J

#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Check TS10 A and TS10 B are locked to the clock source.	TS10 A and TS 10B locked to external reference and their time is identical.		y
2	Check WR link status on TS10 C, TS10 D and TS10 E.. Clock wandering on TS 10 C is on. Check whether RSTU is receiving a valid signal	All WR links go to track phase (synchronized) state, offsets throughout the system are < 1 ns. RSTU input signal is valid.		y
3	Verify status on OPNT Navigator and start collecting data from TS10 F	OPNT Navigator is collecting data from TS10 F		y
4	Check if the frequency measurement devices shows valid results for a period of 10 minutes.	People from JRC confirm that the frequency stability measurement device is taking proper measurements from TS10 D.		y
5	Run the test for 24 hours			y
6	Post process data and verify results between OPNT Navigator and JRC measurements	Measurements agree TS 10 D stays within +/-100ns compared to the initial offset.	Initial offset: 400ns	y





The graphs above show the RSTU results. TS10C (orange line) is introducing a triangle shaped offset of +/- 400ns which is compensated by the RSTU causing TS10D (green line) to stay within +/- 100ns. In order to keep the TICs from wrapping around, a 400ns offset was introduced in TS10D. In a real deployment the results from TS10D would be from an offset of 0 ns.

Overall result: passed

T3B: Fiber link time stability test

See T2J results. Due to the way White Rabbit works, both time and frequency are transferred. This means that the results for T2J also apply to T3B so it was decided not to run T3B.

Objective	The time stability stability tests measures between the 1PPS output of the clock reference and the 1PPS outputs from TS10 E (White Rabbit time transfer) and TS10D (RSTU time transfer)
Output	Time stability data for White Rabbit (fiber link)
Time to execute	Setup: 3 hours? (JRC connections), runtime:3 days
Metrics	quantitative, AVAR, MTIE versus reference clock
Notes	Can be run after T2J/T2K using same setup. Run in parallel with test T3C

#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Check TS10 A and TS10 B are locked to the clock source.	TS10 A and TS 10B locked to external reference and their time is identical.		
2	Check WR link status on TS10 C, TS10 D and TS10 E.. Clock wandering on TS 10 C is on. Check whether RSTU is receiving a valid signal	All WR links go to track phase (synchronized) state, offsets throughout the system are < 1 ns. RSTU input signal is valid.		
3	Verify status on OPNT Navigator and start collecting data	OPNT Navigator is collecting data		
4	Check if the time interval counters shows valid results for a period of 10 minutes.	People from JRC confirm that the time interval counters are taking proper measurements from TS10 E.		
5	Run the test for 14 days			
6	Post process data and verify results between OPNT Navigator and JRC measurements	Measurements agree TS10 E stays within +/-1 ns compared to the clock source, TS 10 D stays within +/-100ns compared to the initial offset.		

T3C: RSTU (radio link) time stability test

See test T2K. Due to the way the RSTU works, both time and frequency are transferred. This means that the results for T2K also apply to T3C so it was decided not to run T3C.

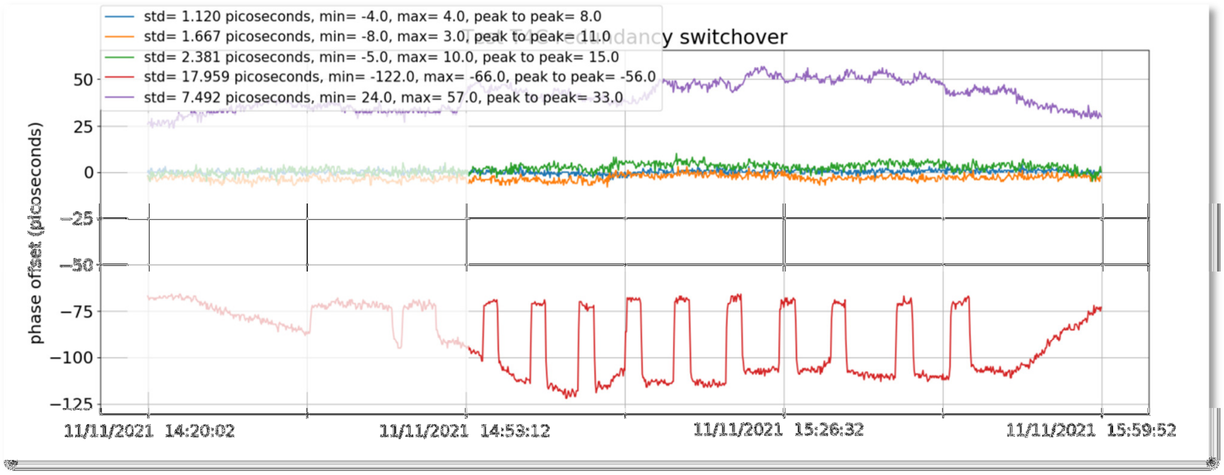
Objective	The time stability test measures between the 1PPS output of the clock reference and the 1PPS output TS10D (RSTU time transfer)
Output	Time stability data for RSTU (radio link)
Time to execute	Setup: 3 hours? (JRC connections) runtime: 3 days
Metrics	quantitative, AVAR, MTIE versus reference clock
Notes	Can be run after T2J/T2K using same setup. Run in parallel with test T3B

#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Check TS10 A and TS10 B are locked to the clock source.	TS10 A and TS 10B locked to external reference and their time is identical.		
2	Check WR link status on TS10 C, TS10 D and TS10 E.. Clock wandering on TS 10 C is on. Check whether RSTU is receiving a valid signal	All WR links go to track phase (synchronized) state, offsets throughout the system are < 1 ns. RSTU input signal is valid.		
3	Verify status on OPNT Navigator and start collecting data	OPNT Navigator is collecting data		
4	Check if the time interval counters shows valid results for a period of 10 minutes.	People from JRC confirm that the time interval counters are taking proper measurements from TS10 D.		
5	Run the test for 14 days			
6	Post process data and verify results between OPNT Navigator and JRC measurements	Measurements agree TS10 E stays within +/-1 ns compared to the clock source, TS 10 D stays within +/-100ns compared to the initial offset.		

T4C Fiber link redundancy / resilience test

Objective	The redundancy test shows the capability to switch from one clock source to the other without causing a jump in time to downstream devices. This feature is essential to provide a uninterrupted service to downstream devices in case of outages or sabotage.
Output	Live graph that shows system behaviour
Time to execute	1 hour setup
Metrics	visual (live graph)

#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Switch RSTU off. Set phase offset on TS10 C to zero (or reboot)	Phase offset is zero		y
2	Check the status of the WR links on TS10 E	Links with priority 1, 2 and 3 in track phase (synchronized) state with clock offsets <2ns		y
3	Disconnect the fiber between TS10 B and TS10 E	Link with priority 2 becomes active slave link on TS10 E without phase jumps in the 1PPS signal.		y
4	Reconnect the fiber between TS10 B and TS10 E	After (about) a 1 minute delay link with priority 1 becomes active slave link on TS10 E without phase jumps in the 1PPS signal.	Wait 2 minutes before reconnecting the link.	y
5	Repeat the previous two steps 5 more times	No phase jumps in the 1PPS signal	Wait 5 minutes before disconnecting the link.	y



The graph above shows the result from the test. Starting from 14:53 the link was disconnected and reconnected 10 times using 2 minutes disconnected / 5 minutes connected intervals. The graph shows the offset of the link remains within 60ps.

Legend

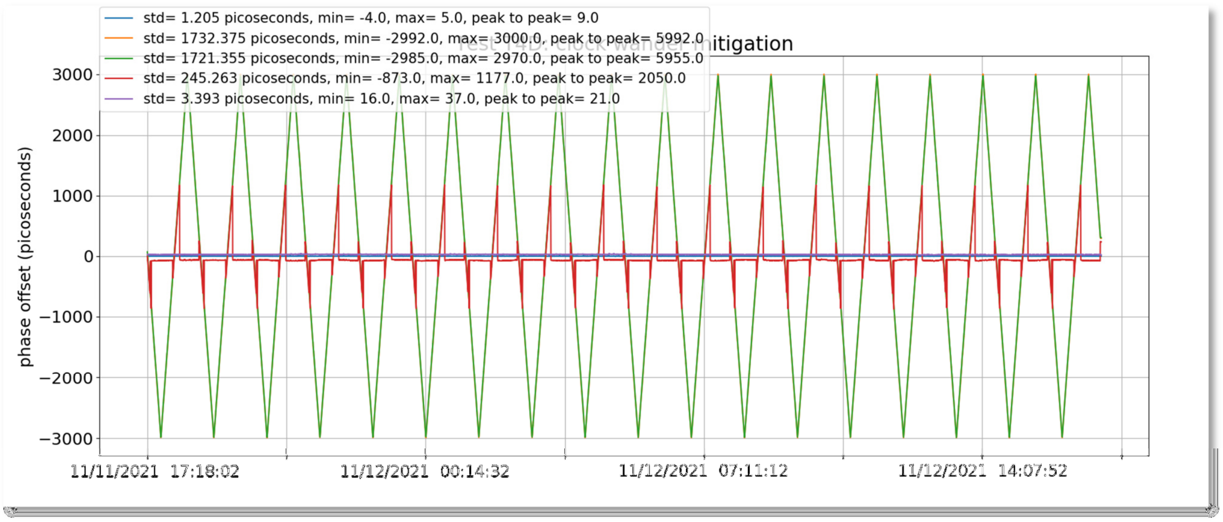
- TS10 A
- TS10 B
- TS10 C
- TS10 D
- TS10 E

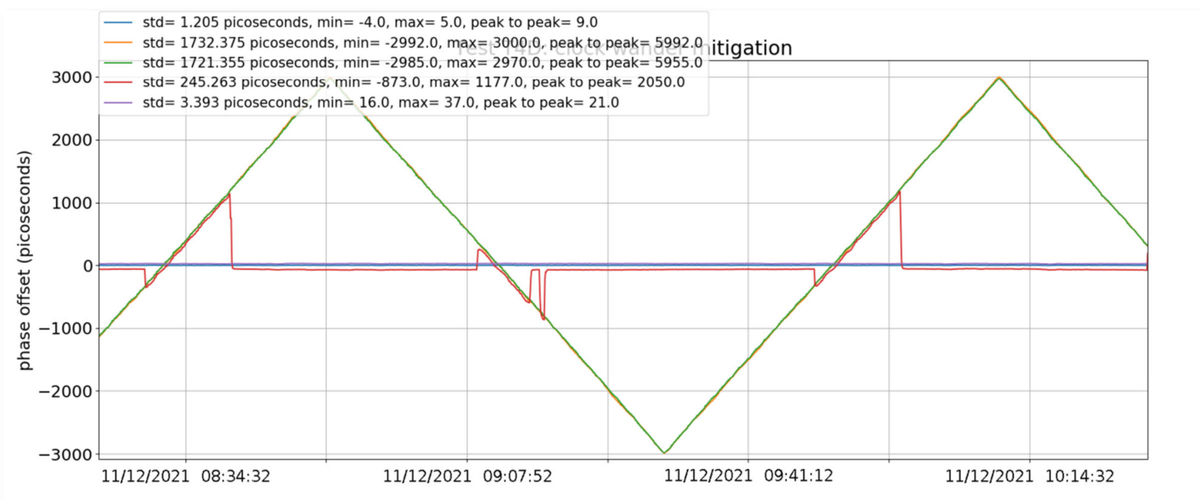
Overall result: passed

T4D Fiber link clock wander/drift switchover test

Objective	The clock wander/drift switchover test shows the ability to detect a deteriorating clock and select a clock source with a more stable clock. This feature is essential to detect sabotage (for example injecting a time offset by a third part).
Output	Live graph that shows system behaviour
Time to execute	1 hour setup
Metrics	visual (live graph)

#	*Test case*	*Expected Result*	*Result/remark*	*OK*
1	Switch RSTU off. Set phase offset on TS10 C to zero (or reboot)	Phase offset is zero		y
2	Set the clock wander limit to +/-30ns on the TS10 E and set the link from TS10 C to P1 and the link from TS10 B to P2	TS10 E is now using TS 10C as the primary clock source.		y
3	Check the status of the WR links on TS10 E using wr_mon	All links in track phase (synchronized) state with clock offset <2ns		y
4	Use the laptop to start the clock wandering on TS10 C with +/-50ns peak to peak value and a cycle time of 10 minutes	Clock offset changes on the links with priority 2 and 3 on the TS10 E		y
5	Let the test run for 1 hour. Check if the TS10 E switches to the link with priority 2 when the clock offset between the links is greater than +/-1ns and switches back to the link with priority 1 when the offset is less than 1ns.	TS10 E switches to priority 2 (from TS10 B) when the offset from TS10 C exceeds 1ns and switches back (after an approx. 1 minute delay) to priority 1 if the offset is below 1ns	Actual runtime: 14 hours	y





The graphs above (with the entire measurement at the top and a zoomed-in section below) that the drift of TS10E (red line) stays within +/- 1ns. TS10C (green line) is used to introduce a +/-3 ns drift (triangular shape).

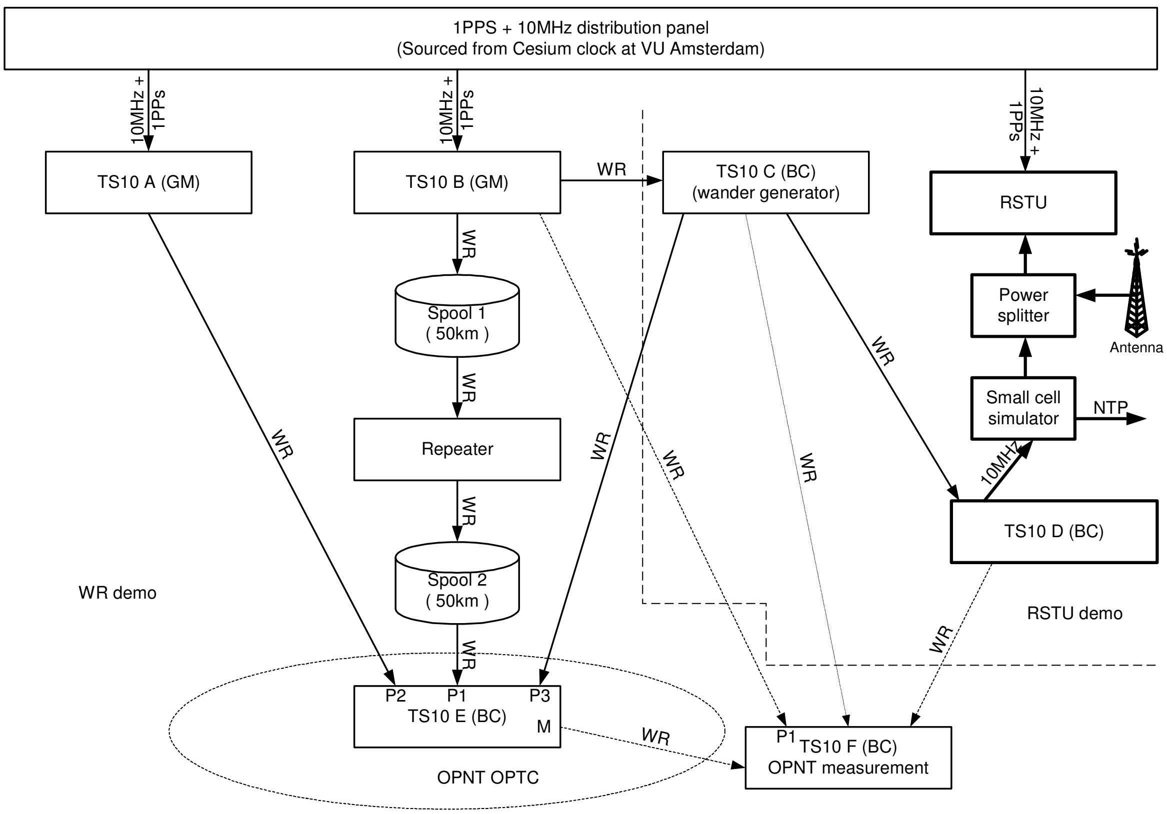
Overall result: passed

T4E RSTU demo

Objective	To show that the RSTU can monitor cell towers and determine their time offset compared to a clock reference.
Output	Graph and numbers
Time to execute	1 hour setup, approx. 24 hour run time
Metrics	quantitative, time offset and variation versus reference clock

Setup

T4E uses a slightly different test setup compared to the previous tests. The direct connection between the RSTU and the small cell simulator is replaced by a power splitter + antenna so the RSTU can receive both the small cell simulator and outside (real) LTE towers.



The small cell transmits on 2120MHz (downlink earfcn = 2050) at low power so the antenna does not transmit a detectable amount of energy. For the outside cell towers the following frequencies where chosen based on a scan for available cell towers: 1815MHz, 950MHz, 816MHz.

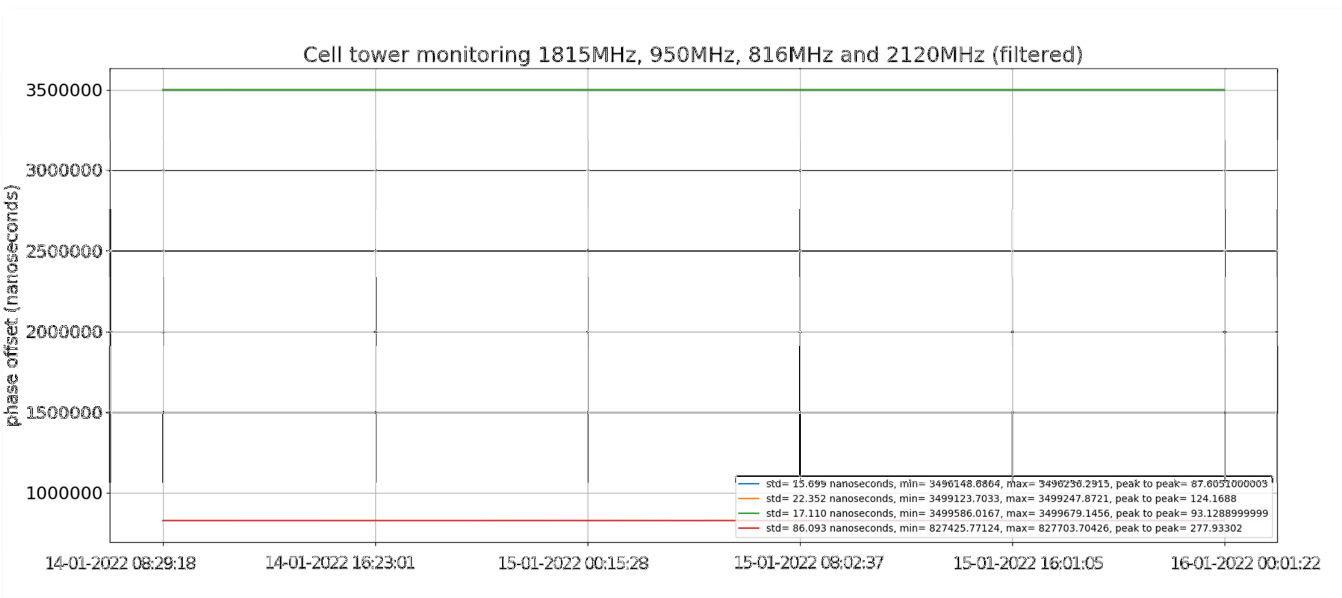
Test plan

#	Test case	Expected Result	Result/remark	OK
1	Set phase offset on TS10 C to zero (or reboot)	Phase offset is zero		y

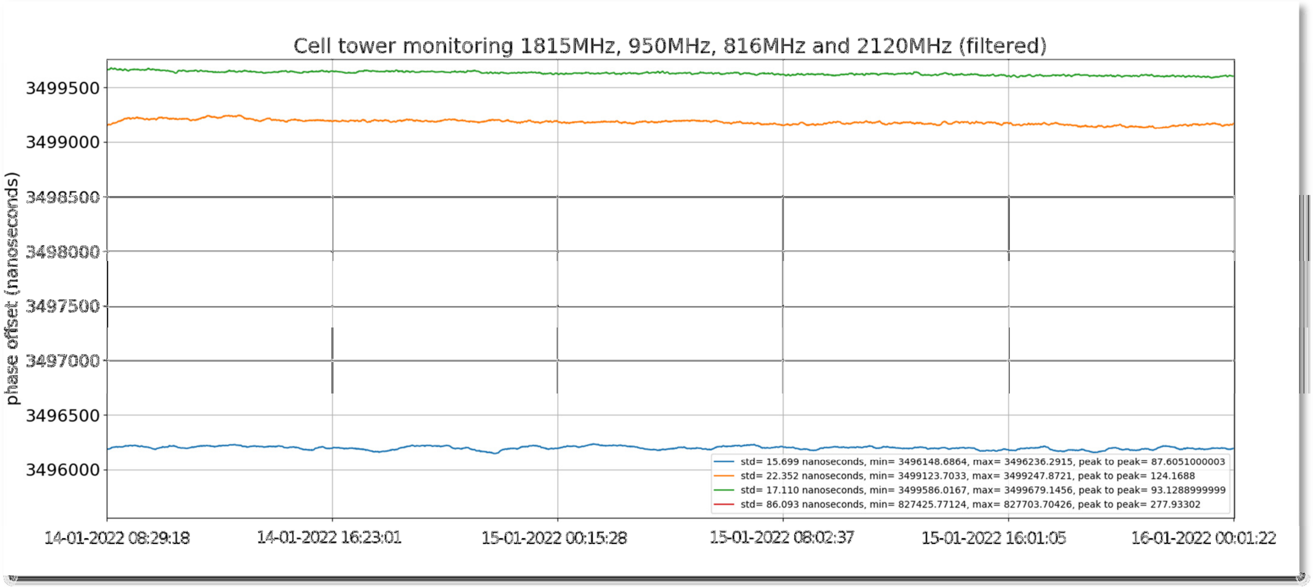
2	Start the small cell transmitter software	Small cell software is running	Transmitting on 2120MHz	y
3	Start the RSTU and check whether it is receiving all frequencies. Note the frequencies used.	Receiving signals from all configured frequencies	1815MHz, 950MHz, 816MHz and 2120MHz	y
4	Start the wander generator on TS10C using a 4000 second period and a 350ns peak to peak wander. Use TS10F to check if the clock offset changes.	Wander generator starts and TS10F shows varying clock offset for TS10C and TS10D		y
5	Let the test run for 24 hours.		Actual run time: 39.5 hours	y

Test results:

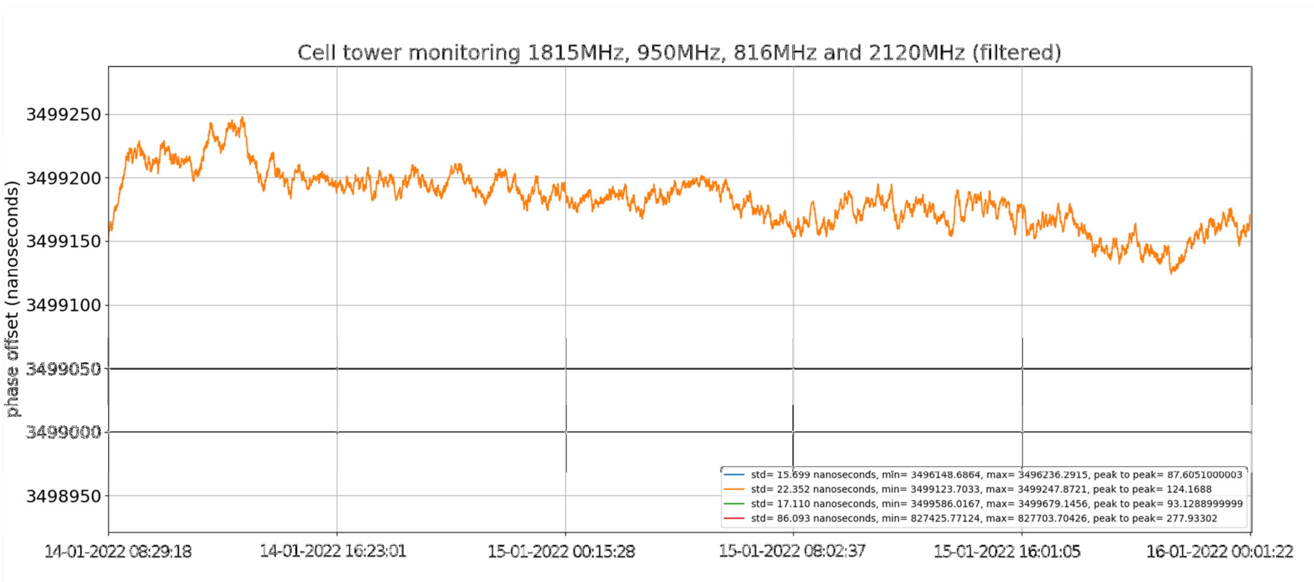
Below an overview of graphs. To make the graphs better readable, the result data was filtered using an averaging filter. The real cell towers are very close together where it comes to the time offset (around 3.5us). The simulated cell tower (2120MHz) has an offset of 0.83us).



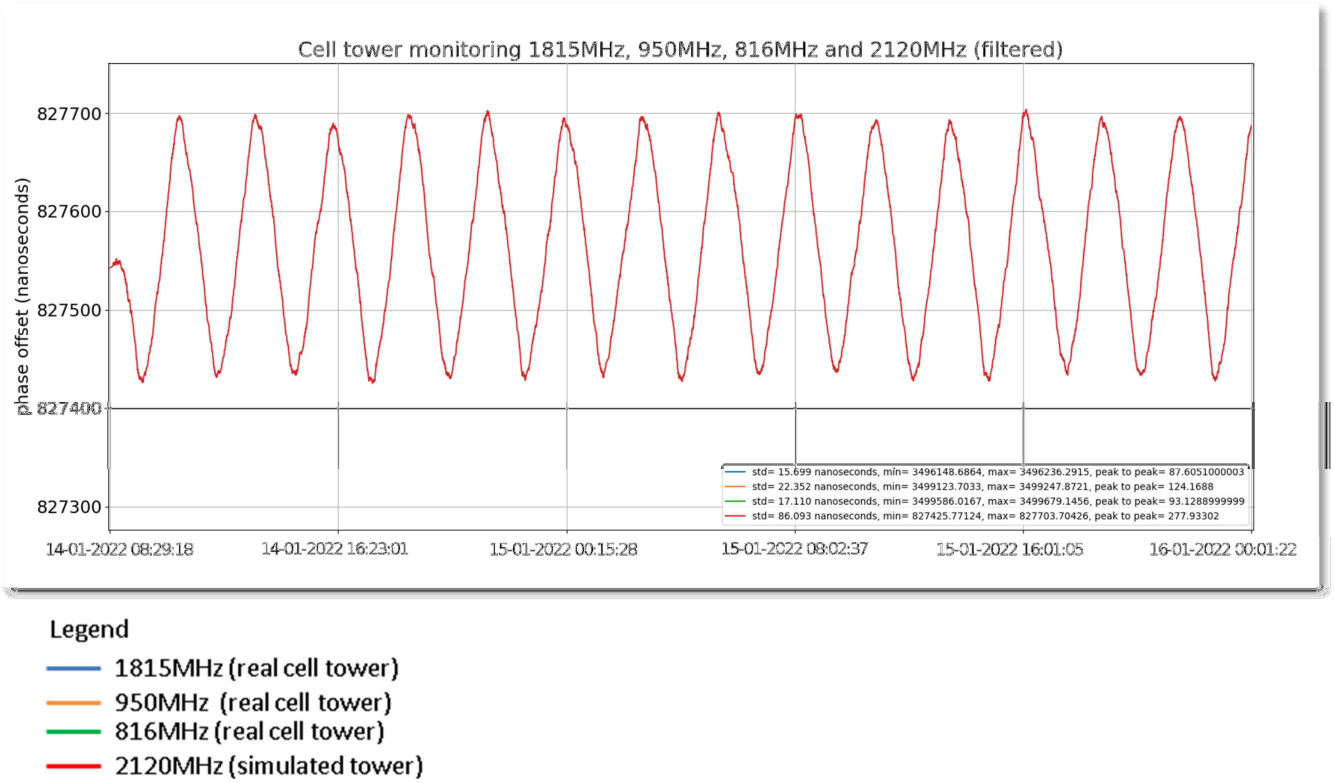
A closer look at the real cell towers. A small drift can be observed in the graphs.



A close-up of the cell tower at 950MHz:



A close-up of the simulated cell at 2120MHz. The introduced wander is clearly visible from the graph and thus showing the RSTU can detect cell towers drifting:

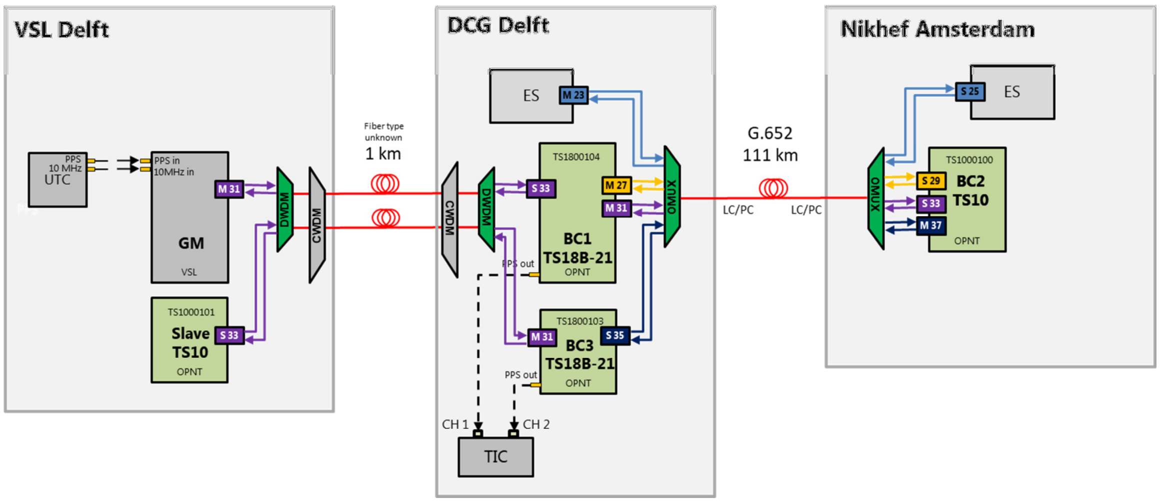


Real world implementation

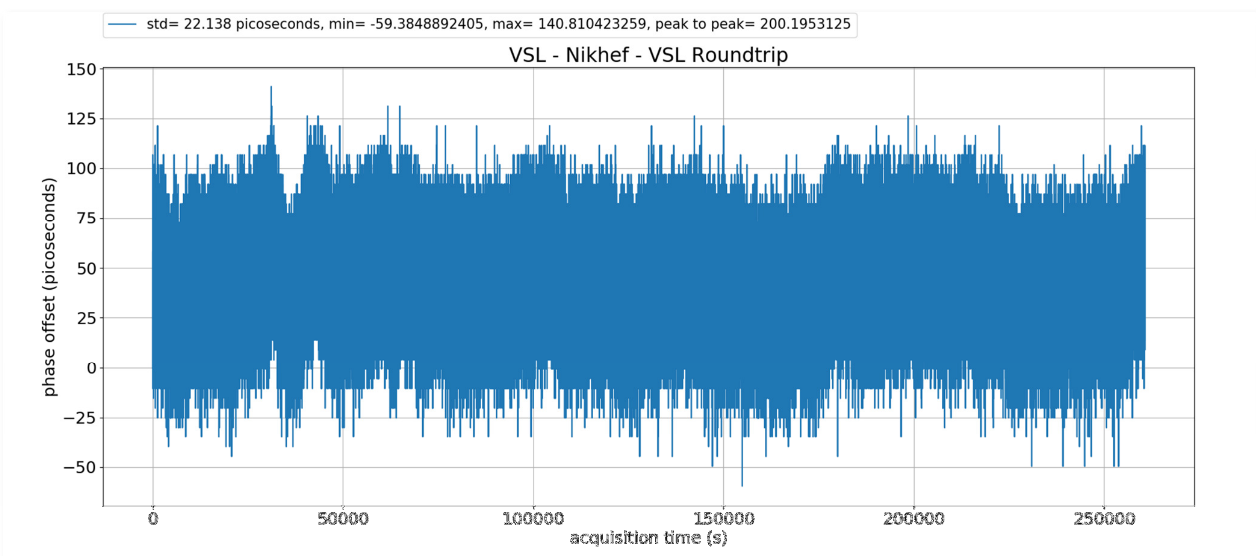
Real world implementation

This chapter describes a link that has been deployed by OPNT between VSL (the Dutch Metrology Institute) and Nikhef (Dutch Institute for Nuclear physics research). The goal of this link is to make measurements on a White Rabbit link in a real world deployment scenario. The report (with measurement results) made by VSL is included as ‘Project reference number 5’.

The link is a loop which goes from VSL (GM) through a datacenter (BC1) to Nikhef Amsterdam (BC2) and returns to the datacenter (BC3) to finally arrive again at VSL (Slave TS10). Because the link is basically a loop, it allows to compare the original signal with the received signal directly.



After the installation a measurement between GM and Slave TS (both at VSL) was taken during 3 days to verify stability of the link:



External connections / equipment

Inputs signals required by the OPNT system

The OPNT system requires 1PPS and 10MHz input references provided by JRC Ispra.

10MHz input reference technical specifications

Item	*Specification*
Coupling	AC
Impedance	50 Ohm
Input level sine wave	From -10dBm to +24dBm. +7dBm typical
Input level square wave	Minimal: 3.3Vpp Maximum: 5Vpp
Connector	SMC male

1PPS input reference technical specifications:

Item	*Specification*
Coupling	DC
Impedance	10k Ohm
Vlow	0.9V
Vhigh	2.1V
Amplitude	Minimal: 3.3V Maximum: 5V
Minimum pulse width	10us
Connector	SMC

Outputs provided by the OPNT system

The OPNT system can provide time and frequency as output in the following formats: 1PPS, 10MHz, White Rabbit, PTPv2, NTP, NMEA.

10MHz output technical specifications

Item	*Specification*
Coupling	DC
Output level	11dBm to 16dBm (3.3Vpp no load)
Waveform	Square
Output impedance	50 Ohm
Connector	SMC

1PPS output technical specifications

Item	*Specification*
Coupling	DC
Output level	3.3Vpp (no load)
Waveform	Pulse
Output impedance	50 Ohm

Connector	SMC

Needed infrastructure

Power: European standard 220-240 VAC.
Room for two 12U 19'' standard telecom racks.
Internet access (preferred).
VPN access (needed by OPNT in case of remote monitoring and management).
Small table/desk and chair (preferred).
Secured room for storing the OPNT equipment.

Participation constraints

As of now, OPNT does not have any special participation constraints or lead times. The only requirements at this moment are that uninterrupted power and mentioned timing signals are supplied to the OPNT system during the duration of the tests and that the OPNT equipment is stored in a secured room which requires authorized access.

Description of interfaces and data format provided

The OPNT system can provide the 10MHz and 1PPS interfaces for performing measurements against the JRC Ispra Time Source. The measurements can be performed using dedicated measurement equipment, such Time and Frequency Interval Counters and/or high resolution oscilloscopes. At JRC Ispra request, OPNT can provide Time Interval Counters for performing measurements, in which case the measurement results will be shared in CSV format.
OPNT can provide performance log files in CSV format and performance graphs in PNG/JPEG format generated by the OPNT Navigator tool.