ASTRON

The LOFAR Clock System

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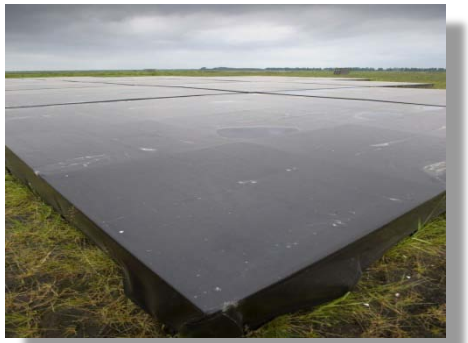
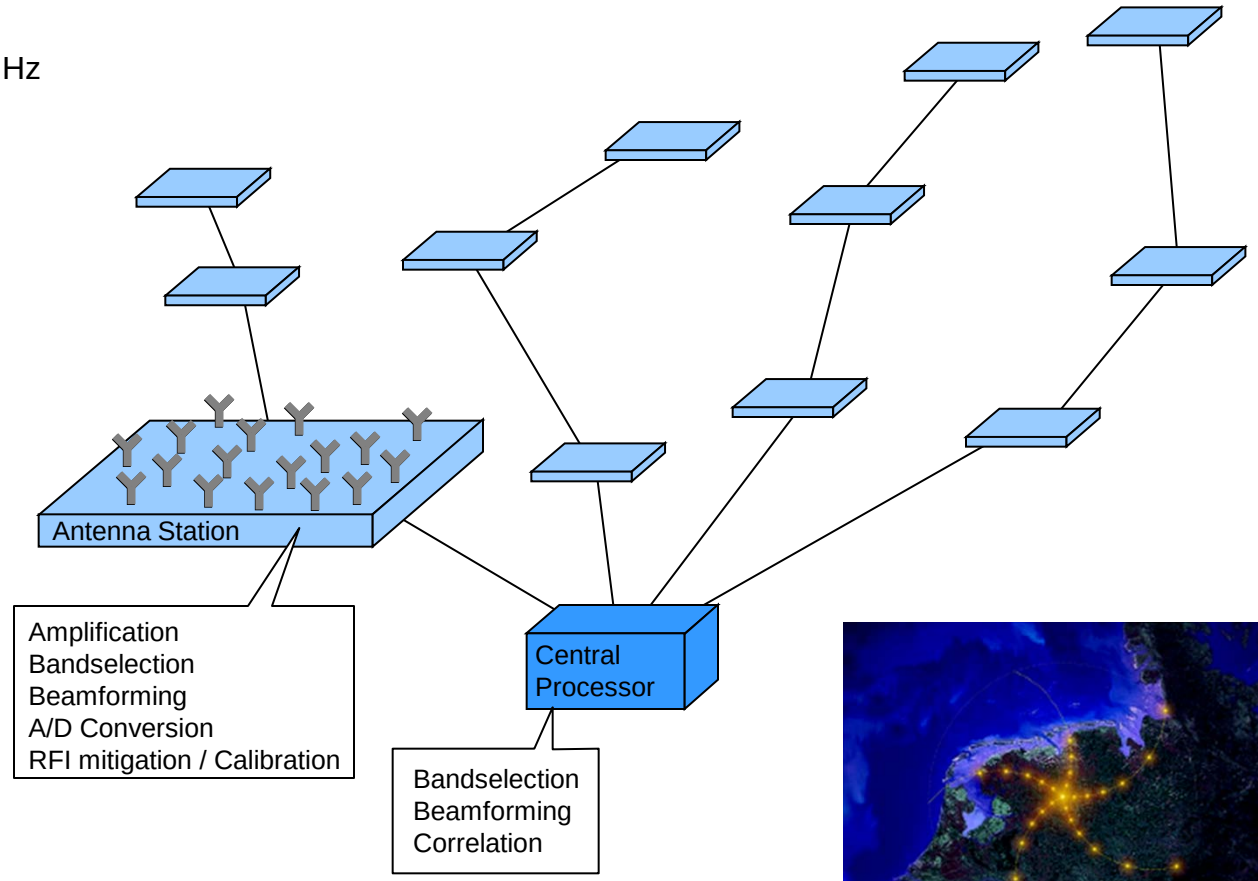
LOFAR

- Frequency range:
  - Low band: 10 - 90 MHz
  - High band: 110 - 250 MHz
- 38 station in the Netherlands
- 12 European stations





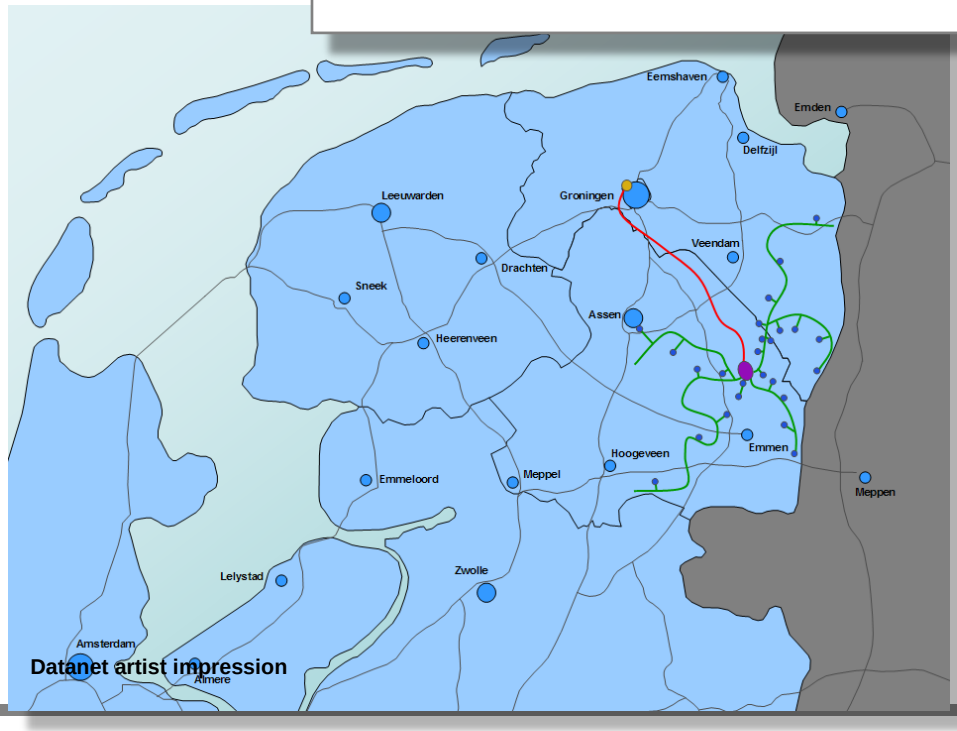
LOFAR

Core Stations:

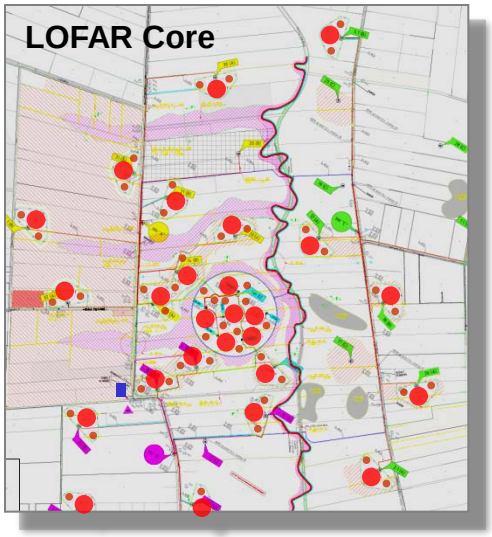
- 24 Stations
- Intra-Core distance < 10 km

Remote Stations:

- 14 Stations
- Distance to LOFAR – Core < 80 km



Datanet artist impression



European LOFAR

Approach:

- Realise connectivity via NRENs
- Connection to CEP via Dutch NREN
- Transportation via 10 Gb/s lightpaths

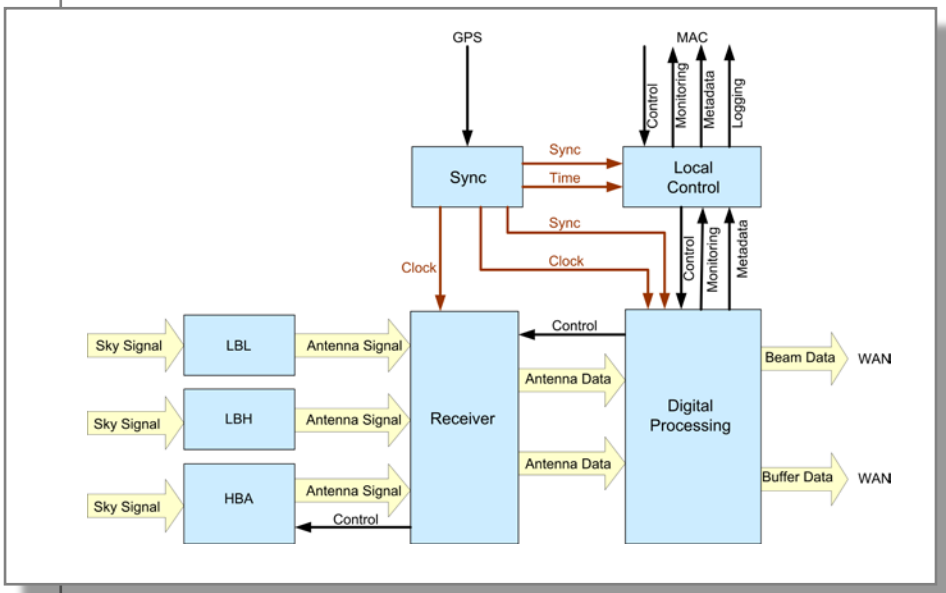
Onsala

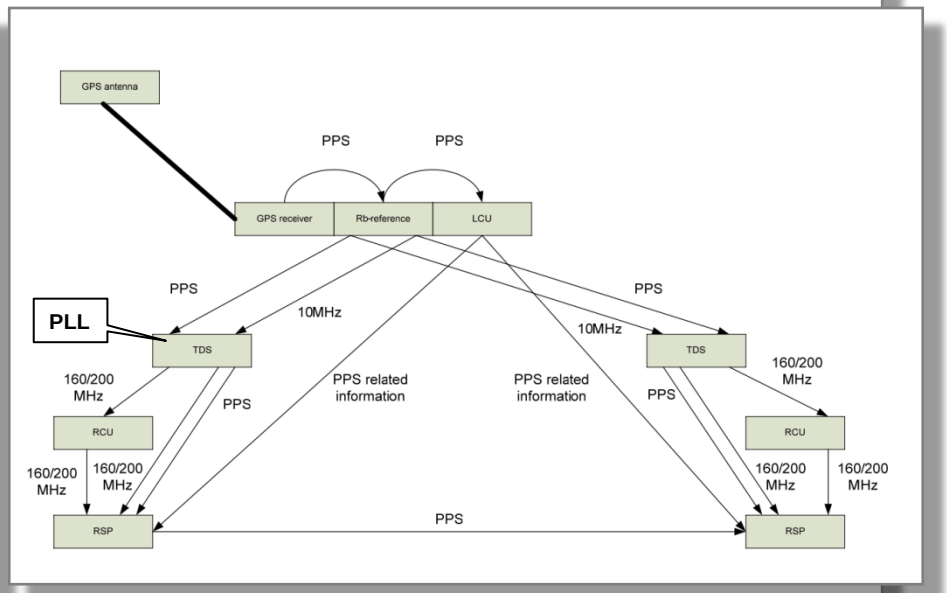
Effelsberg

Station Clocks: Initial Configuration

Each LOFAR station has an independent clock system:

- Rubidium reference clock
- Controlled by a GPS receiver

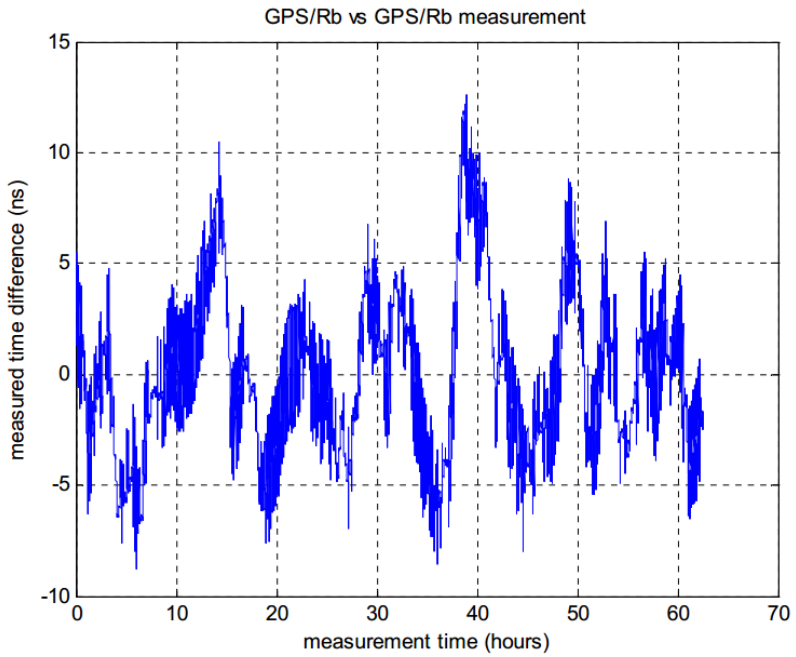




Station Clocks: Initial Configuration

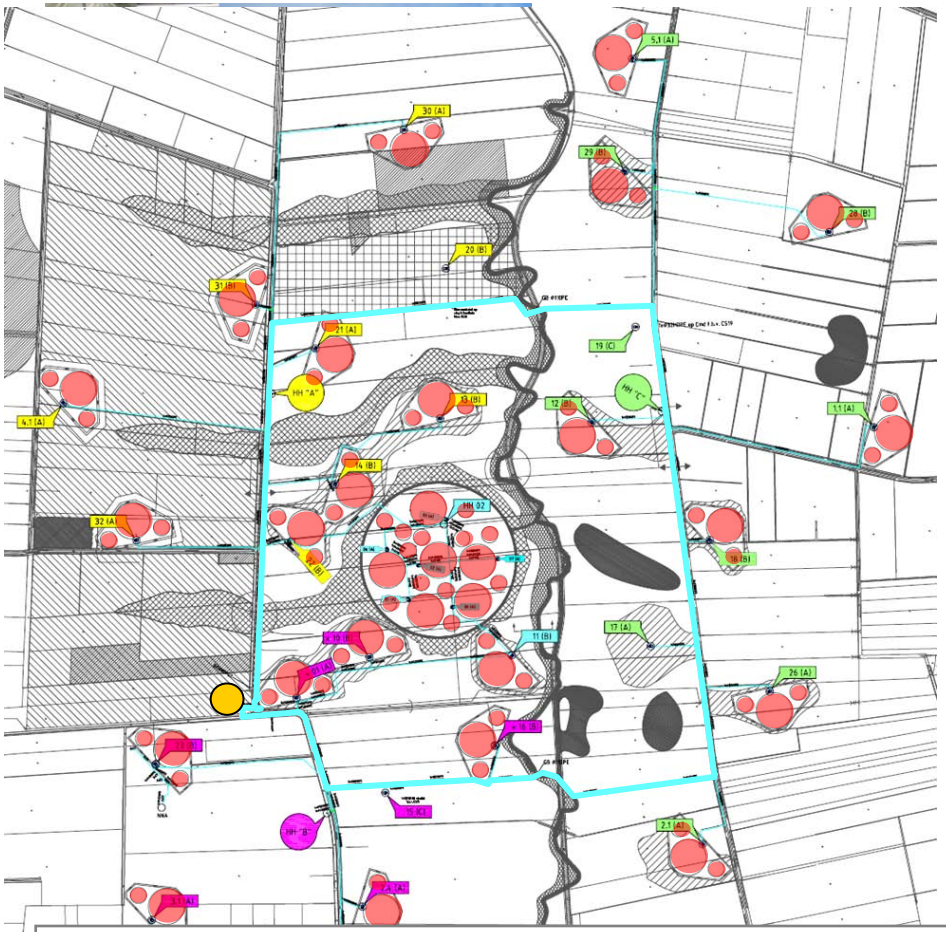
Offset between two GPS/Rb clocks over a 2.5 day period

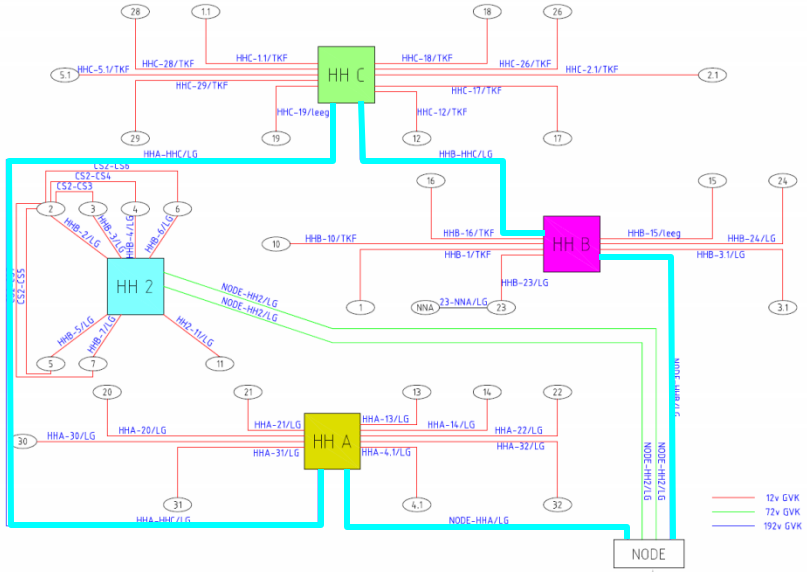
- Maximum offset of 10 ns
- RMS offset of 3.5 ns



➔ Improved stability needed for e.g. tied array observations

LOFAR Datanet: Core Topology

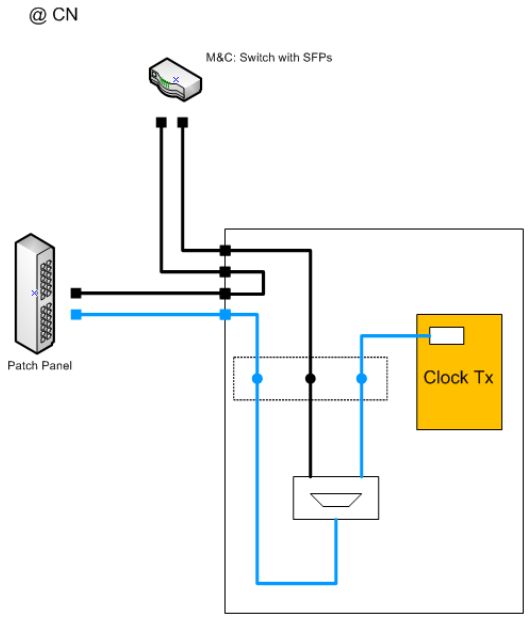


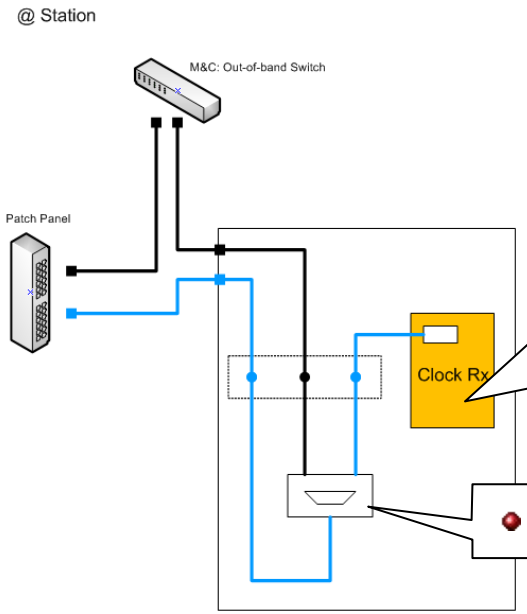


Data links per station:

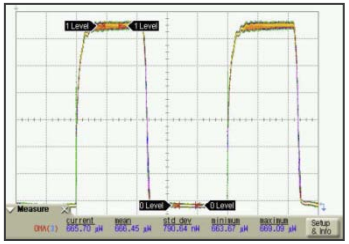
- Observation data: 10Gbase-LX (10 km 10GbE, 1310 nm)
- Monitoring & Control: 100Base-LX (10 km, 100MbE, 1310 nm)

Central Clock for the LOFAR Core

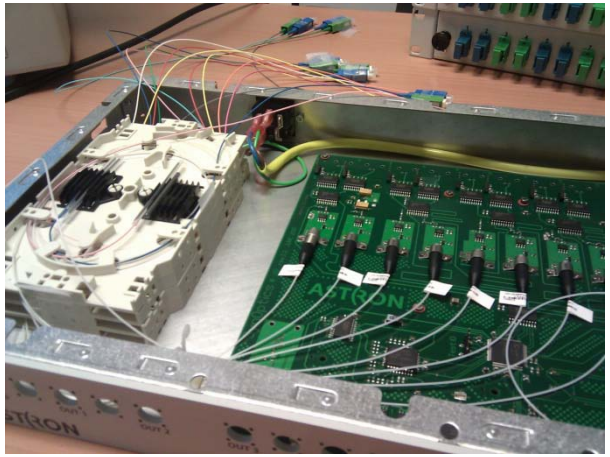


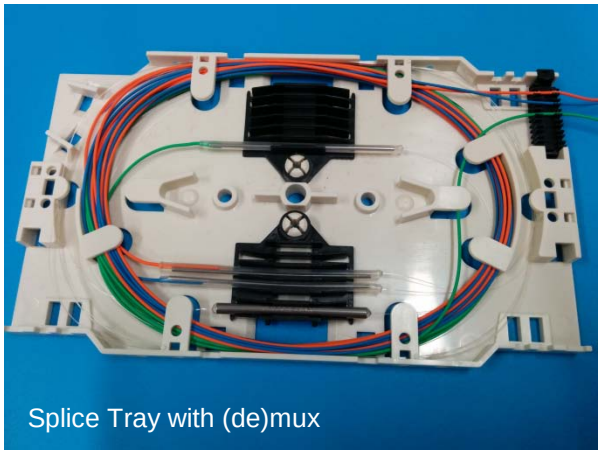


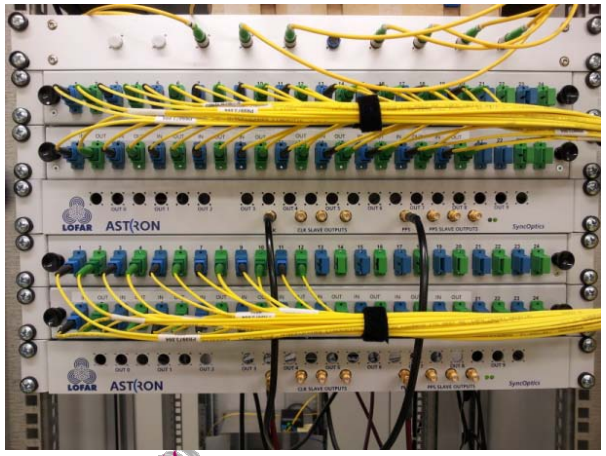
- DFB / PIN detector
  - single mode, 1550 nm
  - 1 GHz bandwidth



- 1310/1550 nm (de)mux



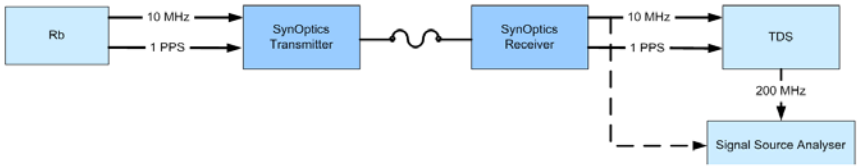

Splice Tray with (de)mux

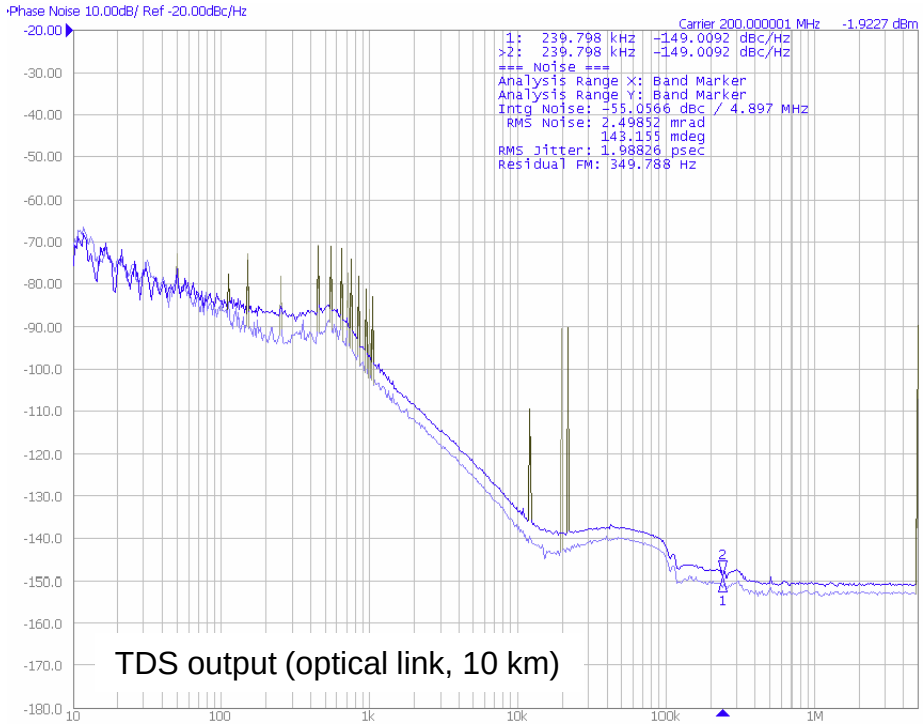


Central Clock for the LOFAR Core

200 MHz phase noise with short and 10 km optical cable

- TDS output (Rb clock), rms jitter: 0.5 ps
- TDS output (optical link b-b), rms jitter: 1.5 ps
- TDS output (optical link, 10 km), rms jitter: 2.0 ps





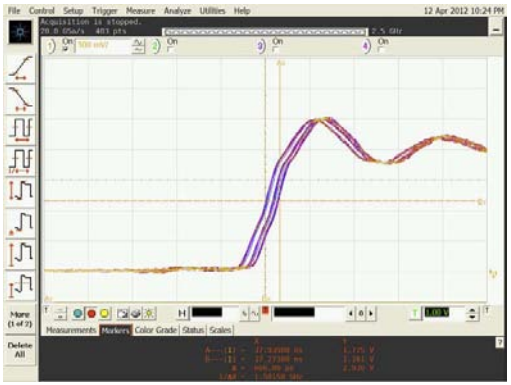
- Temperature effects not taken into account!

Central Clock for the LOFAR Core

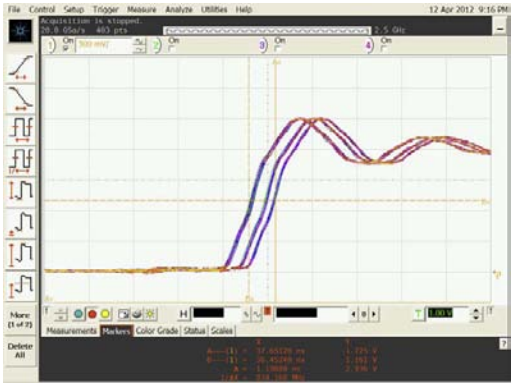
Influence of temperature:

- Receiver: 20 ps/°C
- Transmitter: 40 ps/°C
- Optical Fiber: 466 ps/°C

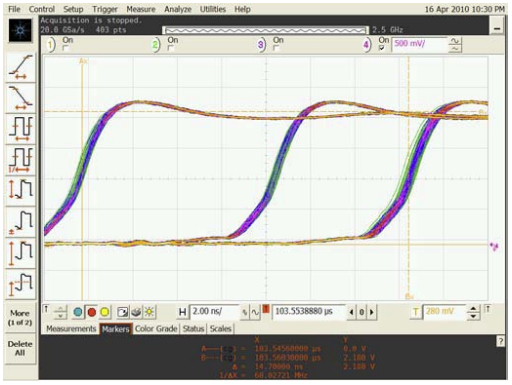
→ Phase change due to receiver & transmitter: 5°/°C @ 240 MHz



Receiver



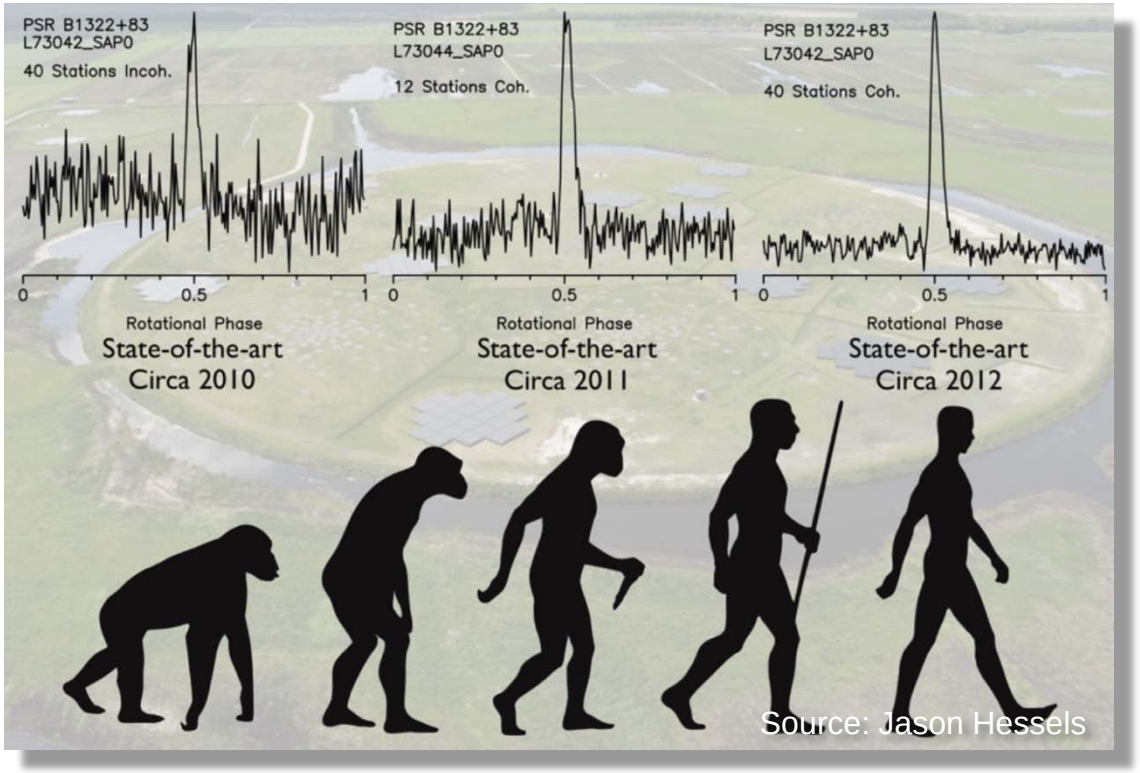
Transmitter



Optical fiber

Central Clock for the LOFAR Core

➔ Time difference ~ 1ns



Possible next steps:

- Reduction of the influence of temperature fluctuations on the phase to reduce calibration effort
- Central clock beyond the LOFAR Core

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