LOFAR 2.0 and the development of station test pipelines

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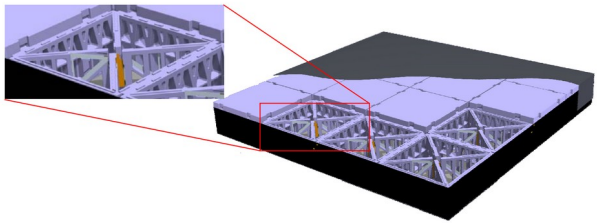
LOFAR & LOFAR 2.0

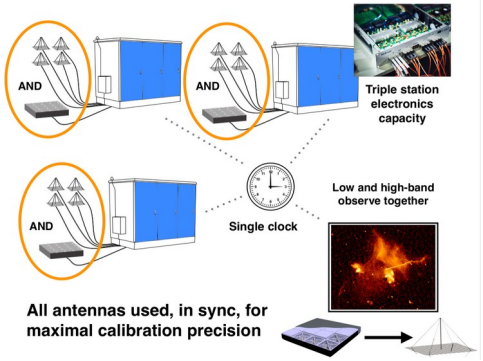
➢ LOFAR: Low frequency array

- **52 stations across Europe.**
- **10 MHz to 240 MHz.**
  - Low Band Antenna (**LBA**): 10-90 MHz.
  - High Band Antenna (**HBA**): 110-240 MHz.
- **LBA:**
  - 96 LBAs at each LOFAR station.
  - In the Netherlands, only 48 LBA are used at once.
- **HBA:**
  - Analogue beam-forming in a tile.
  - **CS:** two 24-tile antenna fields (129 m apart),
  - **HBA tile**: 4 x 4 HBA elements.



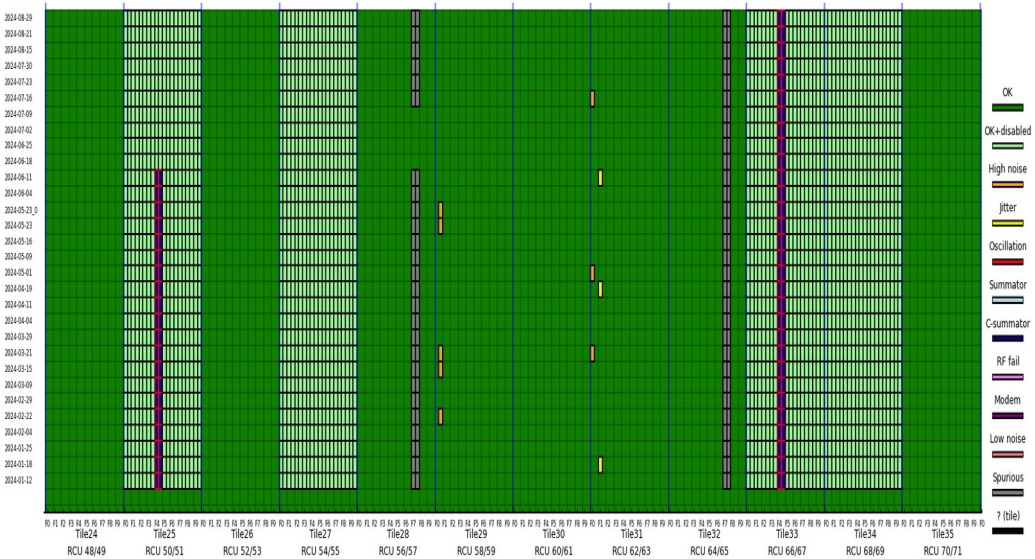
➢ LOFAR 2.0: An upgrade of LOFAR

- **Simultaneous all LBA & all HBA observing.**
- **COBALT2.0:** correlator and beam-former.
- **White Rabbit**: single clock to all NL stations.
- **Italy & Bulgaria**: new international stations.
- **New software system:**
  - **TMSS** : Telescope Manager Specification System.
  - **Station Control and monitoring**: Tango, Jupyter lab, Grafana,
  - **…**
- **New powerful hardware system:**
  - **UniBoard2**
  - **RCU2**
  - **Midplane**
  - **…**

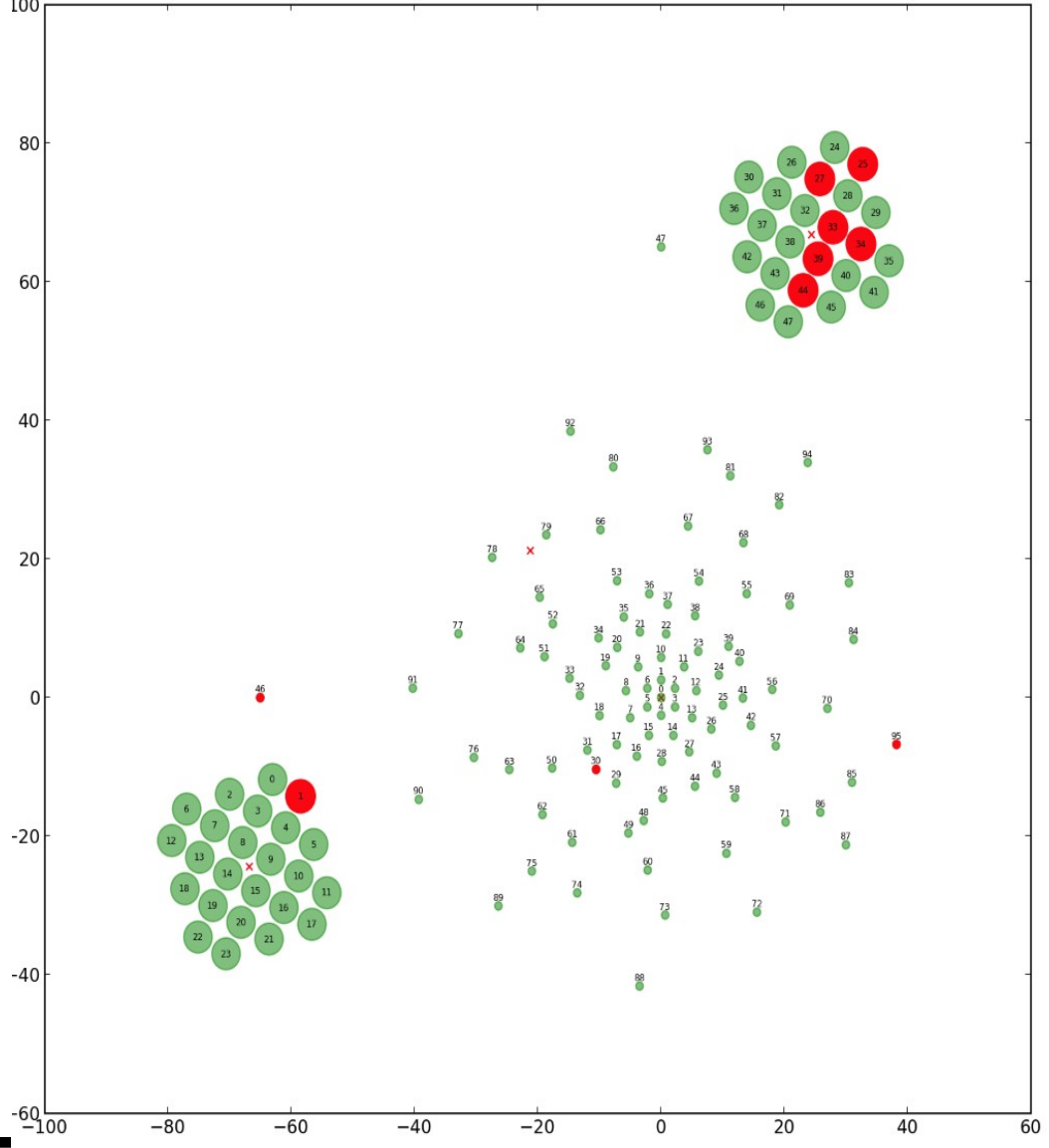


How confident are you

in the data obtained using the antenna array?



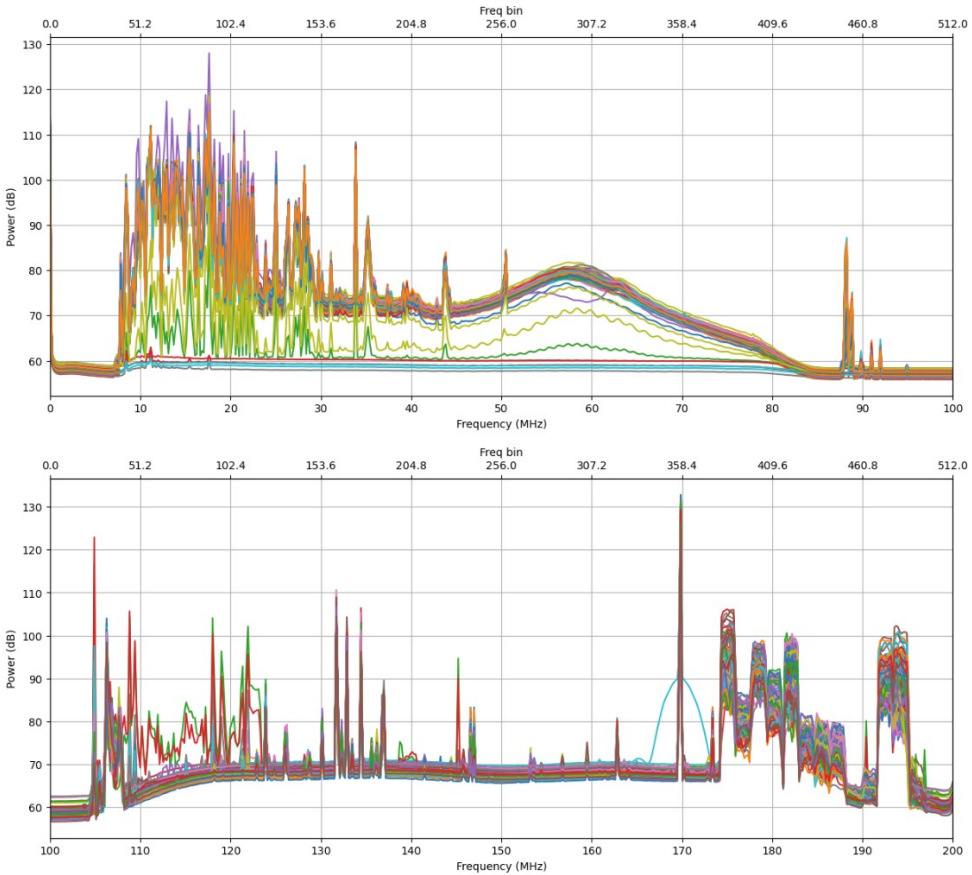
Station CS030 -- Tile032



Motivation for LOFAR 2.0 monitoring and tests

➢ Why test antennas:

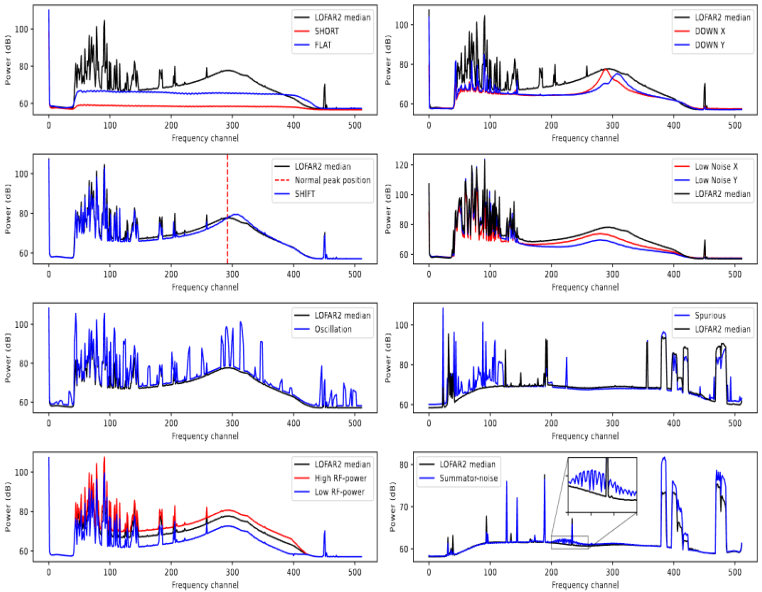
- **Each station is a mini-array.**
  - Thousands of antenna and element.
  - Diverse electronic component.
  - A distributed and complex station environment.
- **System Reliability.**
  - Active bad antennas/elements/electronics impair the system.
  - Identifying anomalies prevents disruptions in the array's operation.
- **Data Quality Assurance.**
  - Faulty antennas can introduce noise or errors, impacting overall data quality.
  - Anomalies in even a few antennas can skew data.
  - Post data quality checks are costly.
- **Efficiency in Maintenance.**
  - Early detection allows for timely maintenance, minimizing downtime.



Antenna tests with LOFAR 1

➢ Test types:

- **LBA:**
  - Short, Flat, Down
  - Spurious, Oscillation, Noise, RF_power,
- **HBA:**
  - Spurious, Oscillation, Noise, RF_power
  - Summator_noise
- **Element:**
  - Modem delays,
  - Spurious, Oscillation, Noise, RF_power
- **Others:**
  - Version check
  - RSP and TBB check



➢ Features/Drawbacks:

- Text (Log and CSV) output.
- Only 48 antennas in each test circle.
- Offline tests occupy too much time.
- Make use of SST only.
- **Limited real-time tests.**
- RCUmode, RSP and TBB tests are not applicable in LOFAR 2.0.

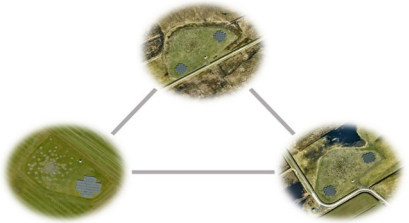
What do we need for a station tests with LOFAR 2.0:

➢ Requirements:

- Use all antennas
- Real **real-time** tests
- **Simultaneous** LBA **&** HBA test
- Fully harness of other statistic data
  - SST: subband statistic
  - BST: beamlet statistic
  - XST: crosslet statistic
- Use existing tests as much as possible.
- Develop new tests.
- Image output for easy check.

➢ Test types for LOFAR 2.0

- **RTSM:** real-time station monitoring
  - Tests can be run during observation
  - All general test for LBA
  - General test for HBA tiles
- Dedicated HBA element-based **Stationtest**
  - Only HBA element tests
  - Switch on/off 16 elements in each tile
  - With different delays for each element.



RTSM: Real-time station monitoring

➢ Real-Time Station Monitoring

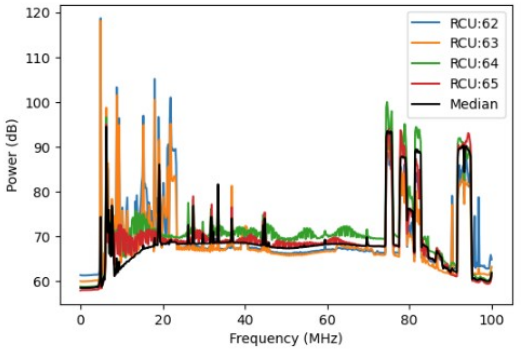
- **Real-time** monitoring during observation.
  - Each circle lasts ~45 seconds (longer circle period can be set as well.).
  - Start/stop time can be pre-defined.
  - Easy to skip some of the tests.
- **Simultaneously** LBA and HBA tests.
  - Test 96 LBA and 48/96 HBA in one time, rather than three.
- At **LBA antenna** level and **HBA tile** level.
- Broken and Beyond Repair antennas not reported again.
- **Log** history and abnormal spectrum (**CSV** format) are recorded.
- **SST**-related tests:
  - Short, flat, down
  - Spurious, Oscillation, Noise, RF_power, Current_Voltages
  - Summator_noise
- **XST**-related tests:
  - Polarization_swap.

```
[11]: parse_file('./logdata/RS307_HBA_20241105.dat')

------------------------------------------------------------------------------------------------------------------------
>>>>>>>>>>>>>>>>>>>>>>>>>>>>  STATION-CHECK RESULTS for 20241105  <<<<<<<<<<<<<<<<<<<<<<<<<<<<
------------------------------------------------------------------------------------------------------------------------
  ==================
  = csv -- (20241105) =
  ==================
-- Station name    : RS307
-- Antenna type    : HBA
-- Frequency band  : HBA_110_190
-- Check runtime   : 2024-11-05
-- Bad antennas    : [23, 31]


== HBA_110_190 SPURIOUS ================================================================================
--check=SPURIOUS, ant=31, rcu=62, rec-timestamp=2024-11-05 10:15:31
--check=SPURIOUS, ant=31, rcu=63, rec-timestamp=2024-11-05 10:15:31
--check=SPURIOUS, ant=32, rcu=64, rec-timestamp=2024-11-05 10:17:31
--check=SPURIOUS, ant=32, rcu=65, rec-timestamp=2024-11-05 10:17:31


== HBA_110_190 SN ======================================================================================
--check=SN, ant=32, rcu=64, rec-timestamp=2024-11-05 10:15:31
--check=SN, ant=32, rcu=65, rec-timestamp=2024-11-05 10:15:31
```



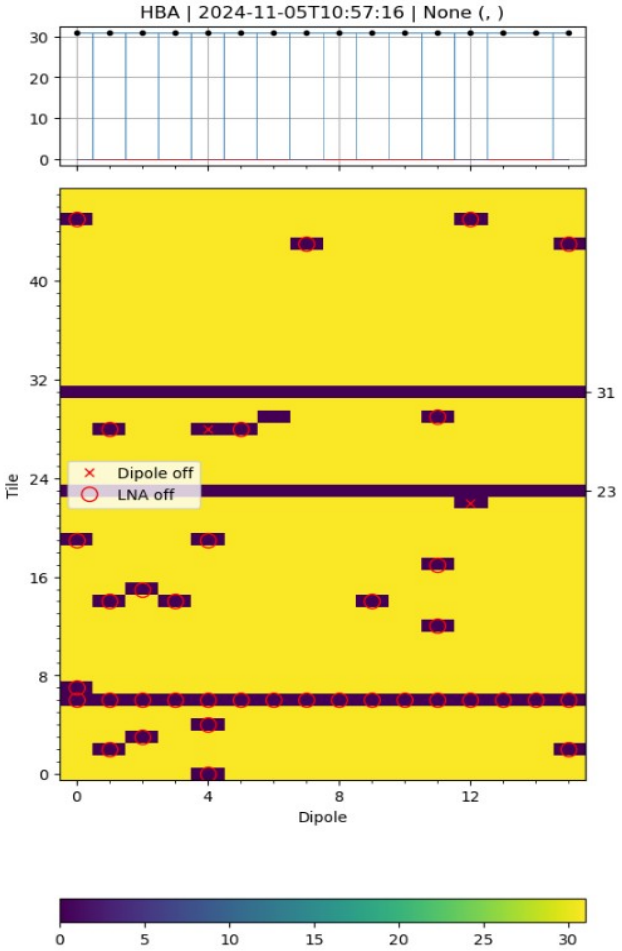
Stationtest: dedicated HBA element-based test

➢ Stationtest (HBA element-based only)

- Modem
- 16 elements in each tile
  - Oscillation, spurious, noise, rf_power
  - polarization_swap, currents/voltages

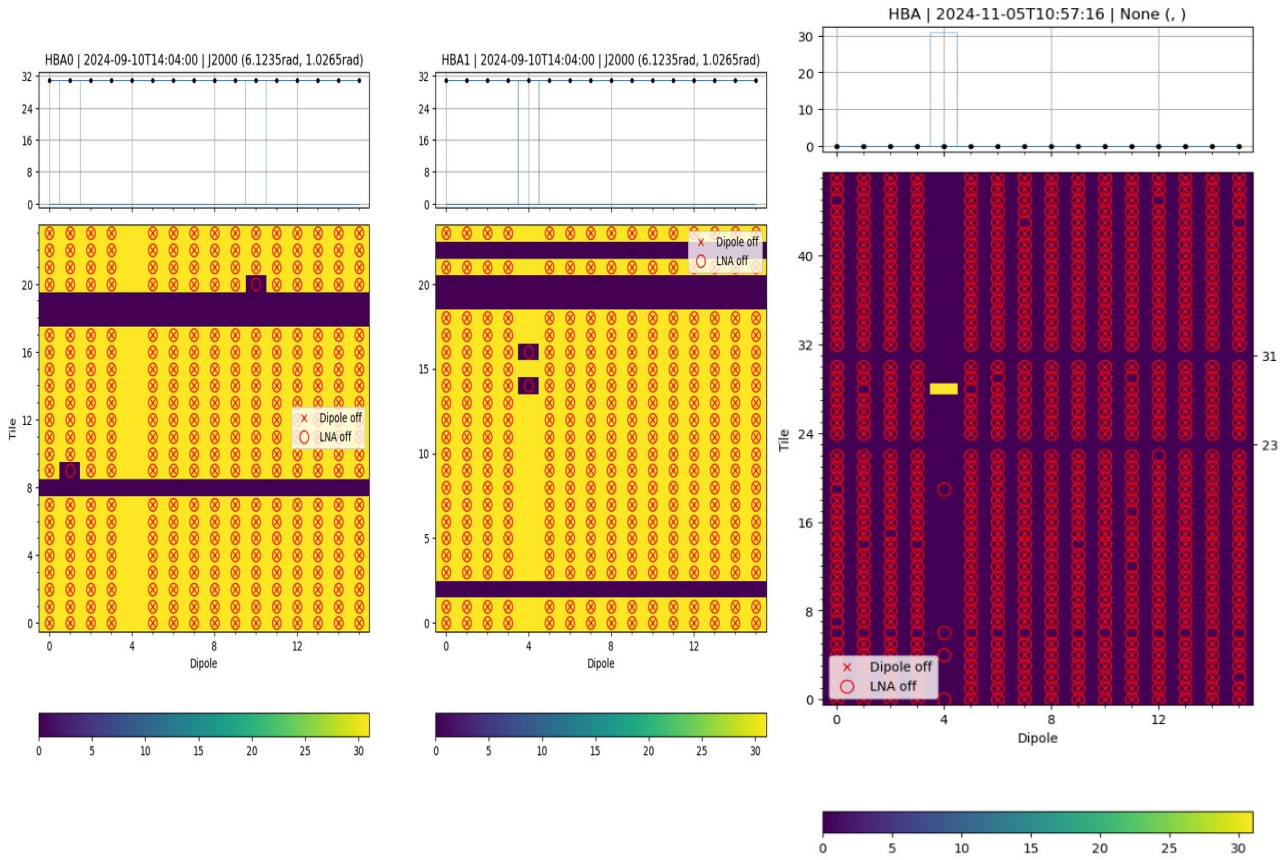
➢ Stationtest procedure:

- Modem test:
  - Send hbadelays to all HBA element and then readback
  - Comparing readback delays with setting hbadelays
  - hbadelays: 0, 0.5, 1, 2, 4, 8, 16, 15.5 ns.
- Element test:
  - Turn on element 0 only in all HBA tiles, and do all test like RTSM
  - Turn on element 1-15 in turn, and redo the test.



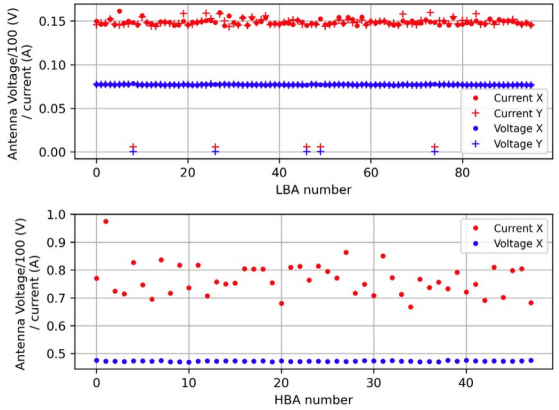
Output of the tests

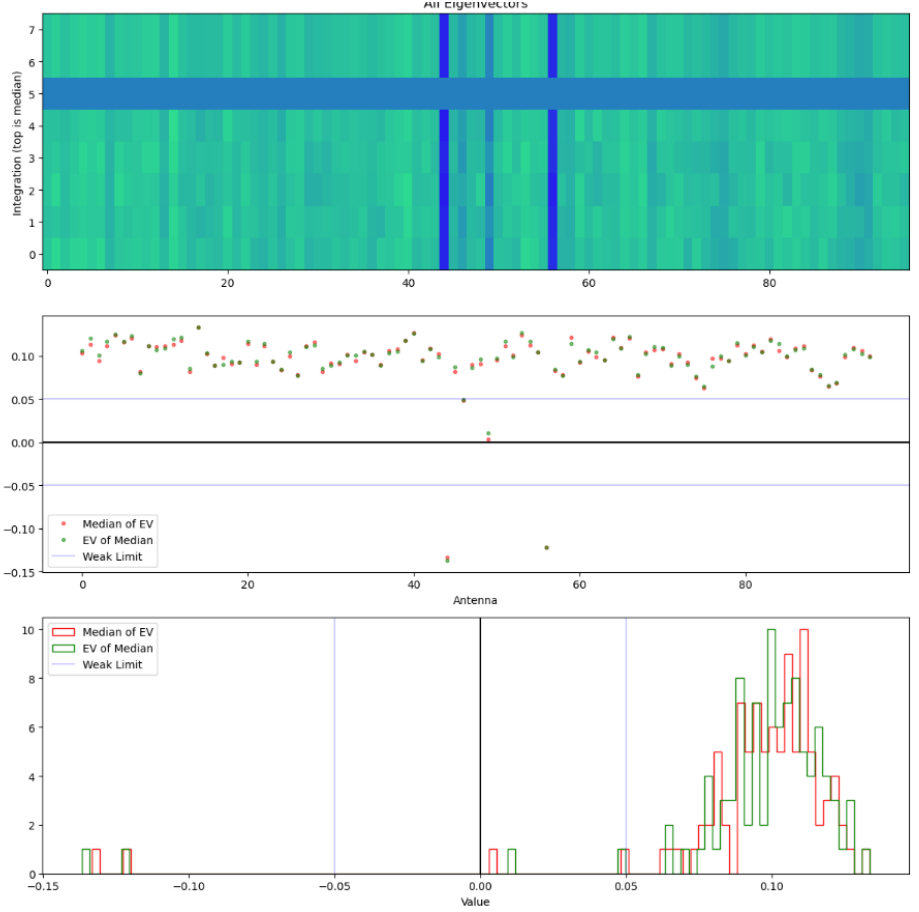
- Log files
  - One log file per day/observation
  - Contains details tests results of all antennas.
- CSV files of anomalous antenna
  - One CSV file per day
  - Contains power spectral of only the anomalous antenna
- Plots of anomaly
  - Can decide plot or not.
  - Clear understanding of the anomalous antenna



New tests for LOFAR 2.0

- LOFAR 2.0 makes new tests possible.
- Currents/Voltages:
  - Measure the current and voltage for short circuit or open circuit
- Polarization Swap:
  - Cables may swapped during assembly
  - Make use of XST data





Summarize

- We have development new test pipelines for LOFAR 2.0
  - Simultaneous all LBA & all HBA test in one cycle
  - Make use of XST data for new tests.
  - Plots output enabled.
- Real-time station monitoring:
  - Real real-time tests during observation.
  - More tests can be taken with RTSM
- Dedicated HBA element-based Stationtest
  - Offline tests for a more specific check on HBA element
  - Modem test.
- New tests enabled in LOFAR 2.0
  - Currents and Voltages tests
  - Polarization swap check.

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