Beam holography

LOFAR2.0 development sprint review

11-04-2024 . Dany Vohl . UvA / ASTRON

Background

Calibration strategies for LOFAR2.0

- Aim:
  - Have (at least) **2 methods** for both **station** and **array** calibration

(previous meetings)

- *David McKenna* discussed the classical station calibration method
- *Emma van der Wateren* discussed imaging delays to assess the beamformer coherence

Background

Calibrate LOFAR's tied-array beams with holography

- Method described in ***Salas, Brentjens, Bordenave, Oonk & Röttgering (2020, A&A)***
  - *Determine* ***time delays between stations*** *in LOFAR core*
  - *LOFAR multibeaming allows to map voltage beam* ***faster*** *than a raster scan*

    ➡ *Simultaneous & continuous beam calibration*

- Same principles to **calibrate at station level** *(Brentjens & Bordenave 2017: https://weblectures.leidenuniv.nl/Mediasite/Play/b4f9b2beea6744138fd7ea4c540aeba51d?catalog=63487fe7-4485-43af-b2d9-de2c2ae2fb79)*

Background

Tied-array holography

- *Determine* ***time delays between stations*** *in LOFAR core*

➡ Two station sets:

➡ **Reference** station points at a bright compact source

➡ **Target** stations (array under test): multibeam at and around source

Figure 2. Sketch of holographic measurements for phased arrays. All beams can be formed at once in post-processing.

Figure 1. Sketch of the holographic measurement procedure for dish antennas. A separate reference antenna stays focused on the calibration source, while the AUT is adjusted to various *lm*-coordinates. The coordinate axes are drawn such that we are looking "down" on both the antennas and the sky.

Kiefner et al. 2021

Kiefner et al. 2021

Figure 2. Sketch of holographic measurements for phased arrays. All beams can be formed at once in post-processing.

Observed beam

Model beam

Residual

Kiefner et al. 2021

Figure 10. Overlay of an aperture image with an aerial drone photo of the EDA-2. The aperture image is partially transparent, and antenna dipoles can be seen in the locations of the peaks in the aperture as expected.

Salas et al.

Background

Tied-array holography

- Aims here:
  - Make code user-friendly (eventually for LOFAR2.0 operators)
  - Make code modular (simplify updates in method / new test / modes)
  - Make code faster? (e.g. A. Gopinath's fast imaging to search for FRBs)

Update

Tied-array holography

- ***holog*** (P. Salas) (which relies lightly on ***taholog*** by M. Brentjens)

1. Converted from Python 2 to 3, and containerized to singularity
    - Tested to reproduce results w/ Salas et al. original observations (L697741)
2. Refactored code for **modular** runs
    - **Profiled** the code per step to evaluate bottlenecks
    - For a 60 second observation:
        - Single-threaded mode: ~**12 hours** ; Multi-threaded w/ 16 cores ~**2 hours 20 min**

Further development

Updated observation strategy with TMSS: *updated data structure*

- Gathered recent observation through TMSS (w/ C. Bassa) to reproduce original observation
- Now stored into a single HDF5 file as different beams. The test station was recorded by itself.
- Long term, best to simply schedule a single observations that would include both the reference and test stations into a single file (and hence, need only to schedule a single observation, instead of two simultaneous observations).

Current and next steps

LOFAR2.0

- Finish fixes to new format
- Enable FFTs and correlation onto GPU
- Documentation & tests

johnaparker.com/blog/fft_2d_performance