LOFAR2.0 Capabilities

Cees Bassa

On behalf of LOFAR2.0 development and commissioning teams

LOFAR data school 2024

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What is changing in LOFAR2.0?

Current LOFAR:
Dutch stations:
- 2x48 digital inputs
  (half LBA dipoles *or* all HBA tiles)
- Separate clocks at remote stations

LOFAR2.0:
Dutch stations:
- 3x(2x48) digital inputs
  (all LBA dipoles and all HBA tiles)
- Single clock and frequency
  distribution system (White Rabbit)

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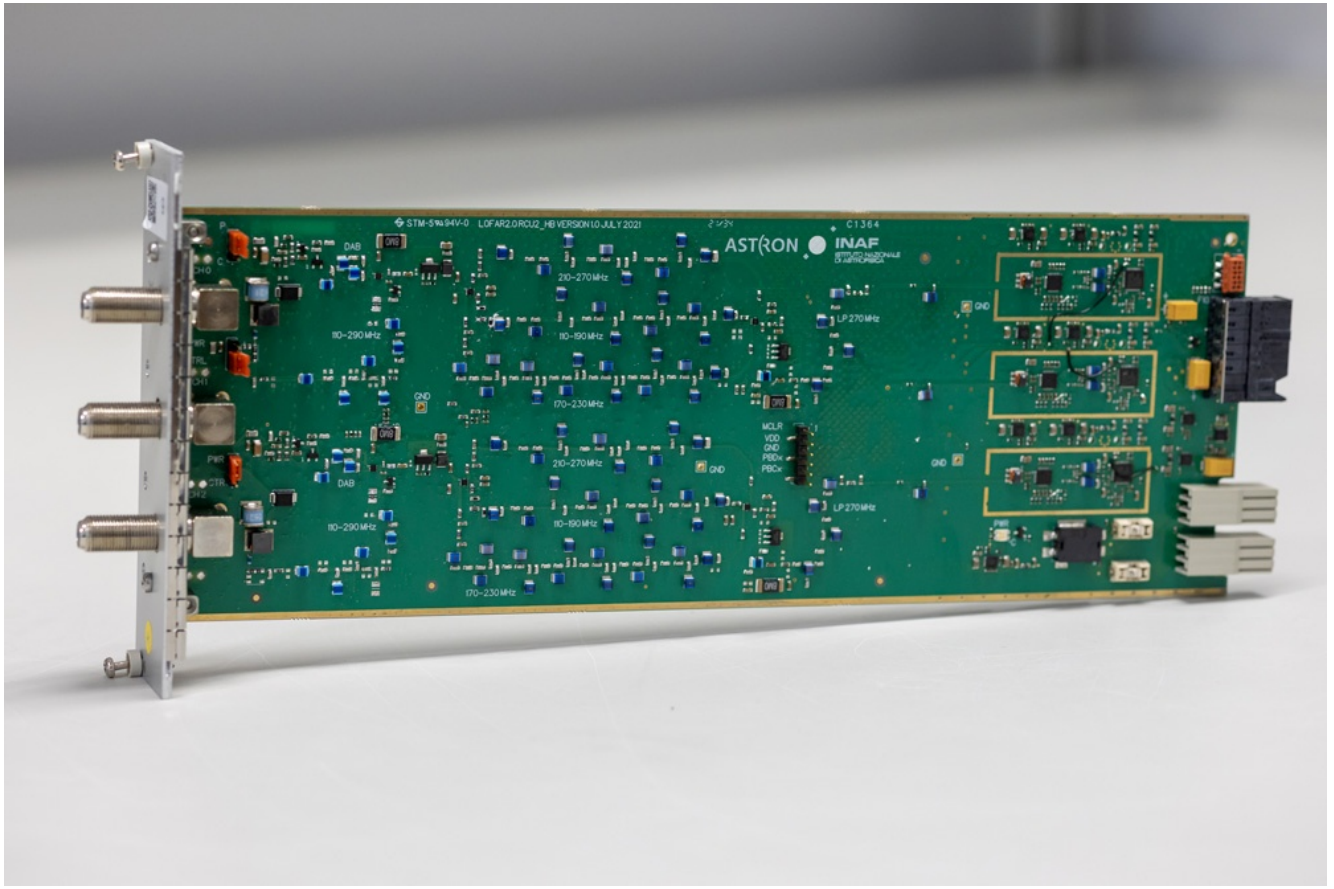
LOFAR2.0 hardware: receiver unit (RCU)



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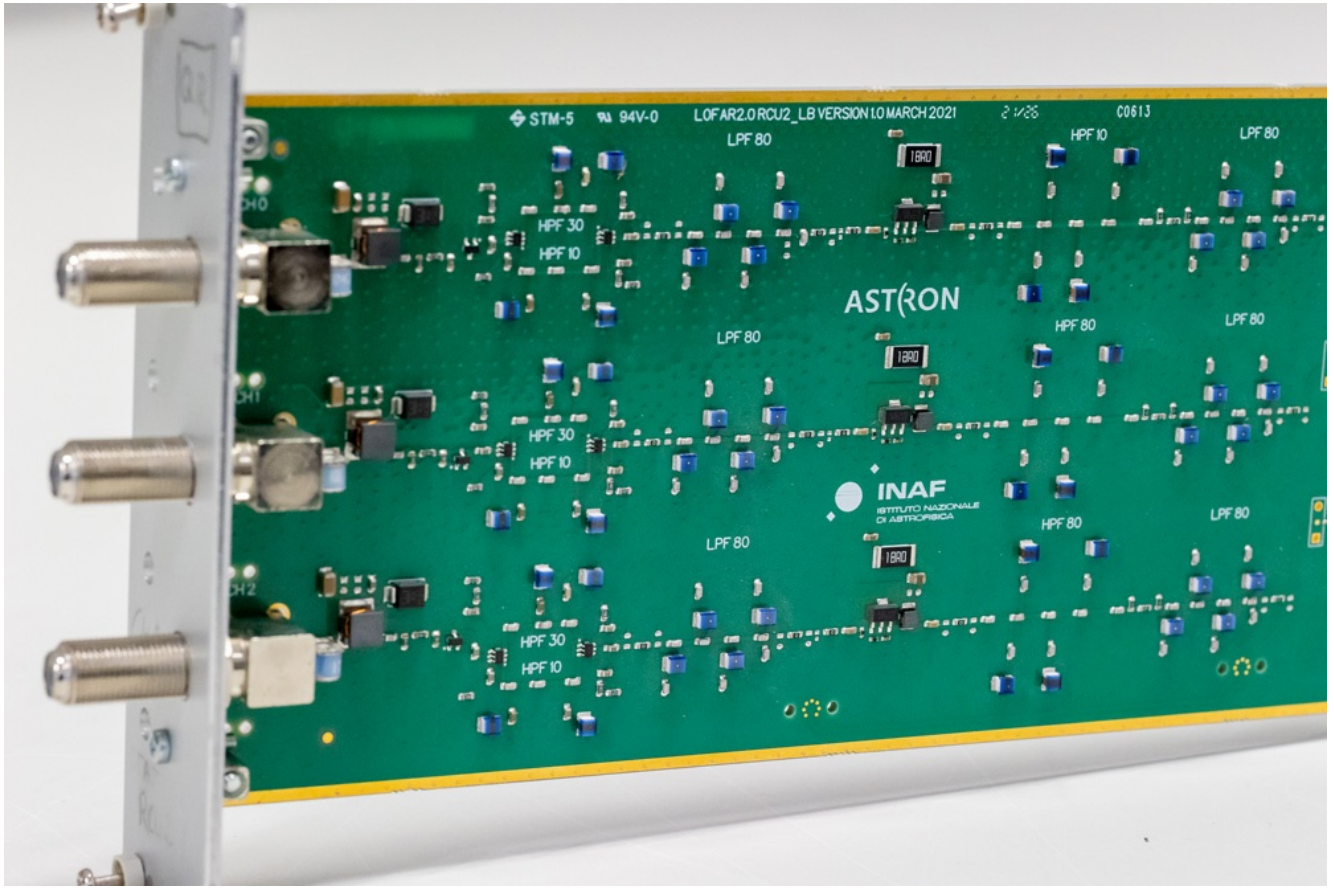
LOFAR2.0 hardware: receiver unit (RCU)



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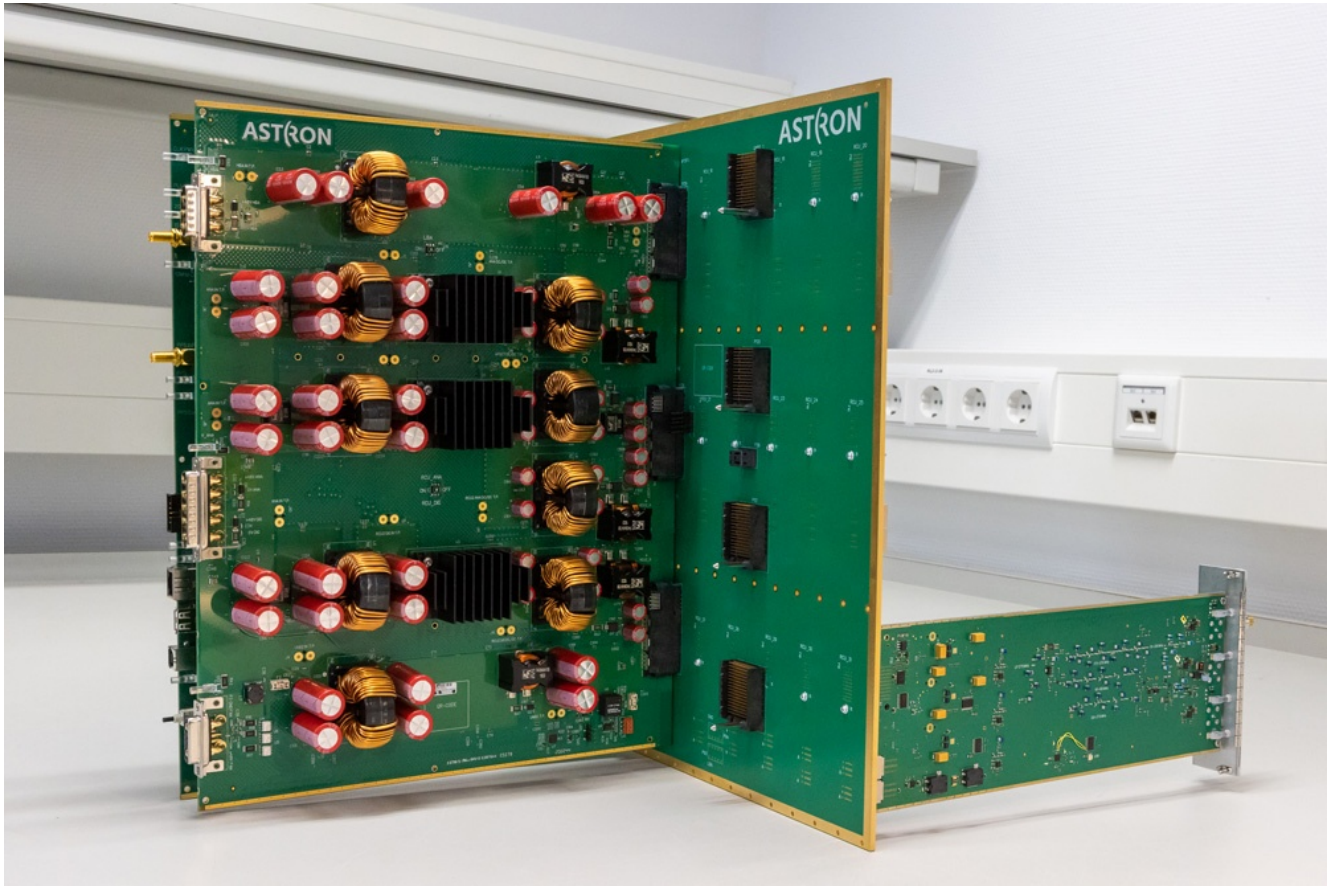
LOFAR2.0 hardware: subrack assembly



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LOFAR2.0 hardware: subrack assembly

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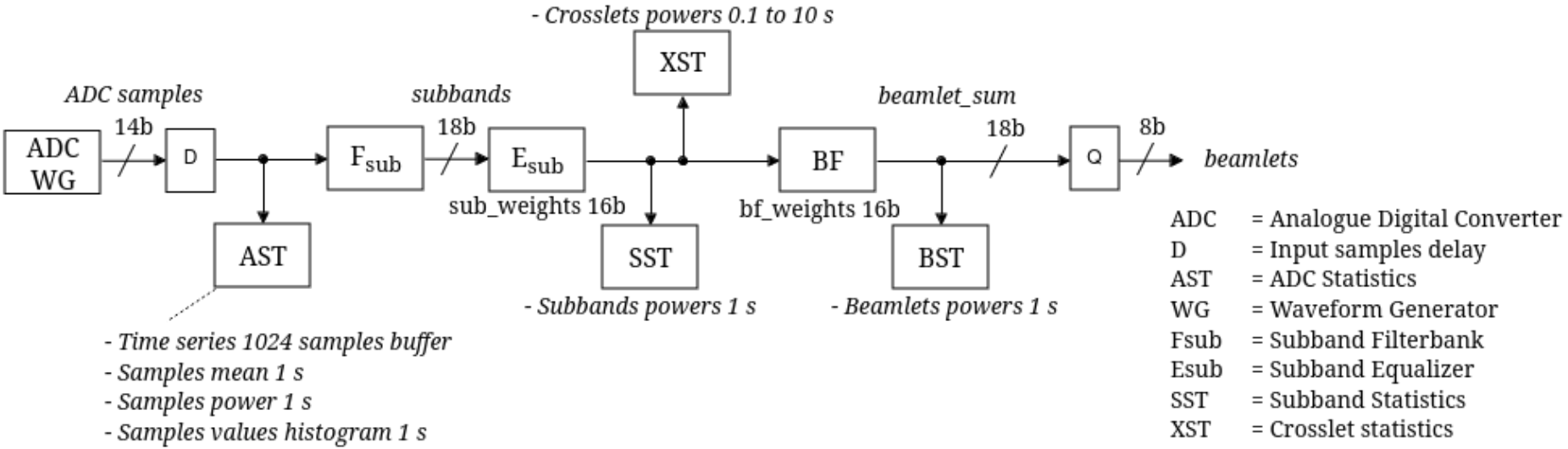
LOFAR2.0 firmware



ADC	= Analogue Digital Converter
D	= Input samples delay
AST	= ADC Statistics
WG	= Waveform Generator
Fsub	= Subband Filterbank
Esub	= Subband Equalizer
SST	= Subband Statistics
XST	= Crosslet statistics
BF	= Beamformer
BST	= Beamlet Statistics
Q	= Requantize

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LOFAR2.0 control software

Markdown git StationControl

Broken Antennas

[26]:
```python
# Set antenna quality
# See explanation at: https://git.astron.nl/lofar2.0/tango/-/blob/master/tangostationcontrol/tangostationcontrol/devices/antennafiel
# OK = 0, SUSPICIOUS = 1, BROKEN = 2, BEYOND_REPAIR = 3

# LBA
antenna_dict_l = {0: [],
                  1: [43],
                  2: [],
                  3: [84, 89]}

# HBA0
antenna_dict_h0 = {0: [],
                   1: [],
                   2: [8],
                   3: []}

# HBA1
antenna_dict_h1 = {0: [],
                   1: [],
                   2: [19, 20, 22],
                   3: []}

# Set antenna
for antennafield, antenna_dict, field in zip([antennafield_l, antennafield_h0, antennafield_h1], [antenna_dict_l, antenna_dict_h0, a
    antenna_quality = np.zeros_like(antennafield.antenna_quality_r)
    nant = len(antenna_quality)
    for idx in range(4):
        for antenna in antenna_dict[idx]:
            antenna_quality[antenna] = idx
    print(field, np.arange(nant)[antenna_quality > 0], antenna_quality)
    antennafield.put_property({"Antenna_Quality": antenna_quality})
    antennafield.Off()
    antennafield.Initialise()
    antennafield.On()
```

```
LBA [43 84 89] [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 3 0 0 0 0 3 0 0 0 0 0 0]
HBA0 [8] [0 0 0 0 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
HBA1 [19 20 22] [0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 2 2 0 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0]
```

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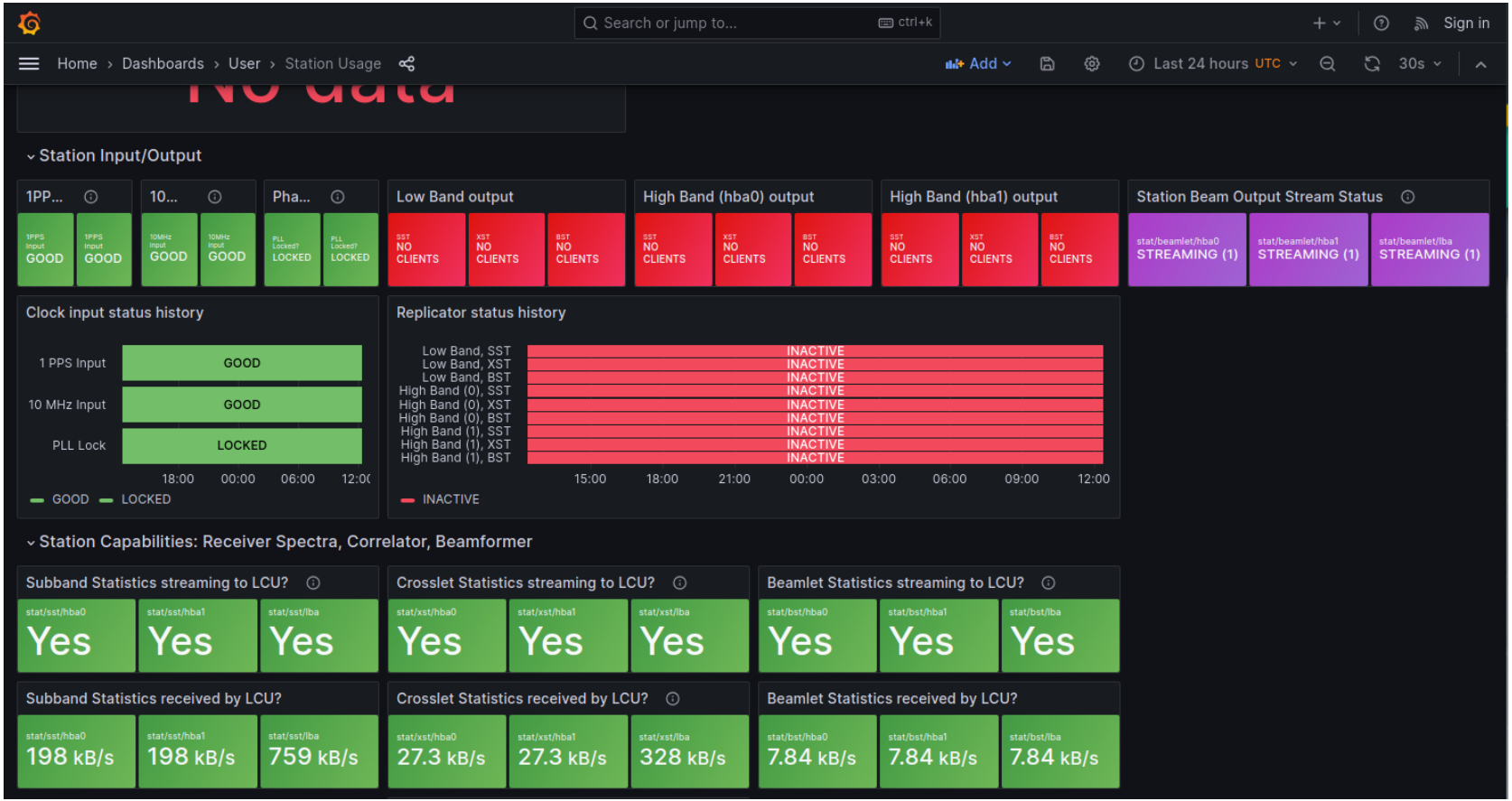
LOFAR2.0 monitoring



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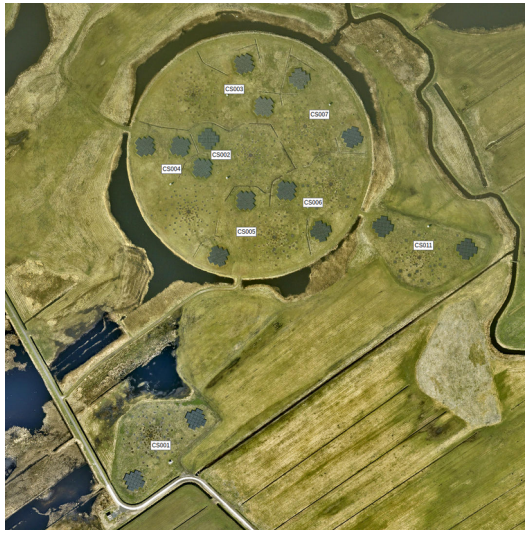
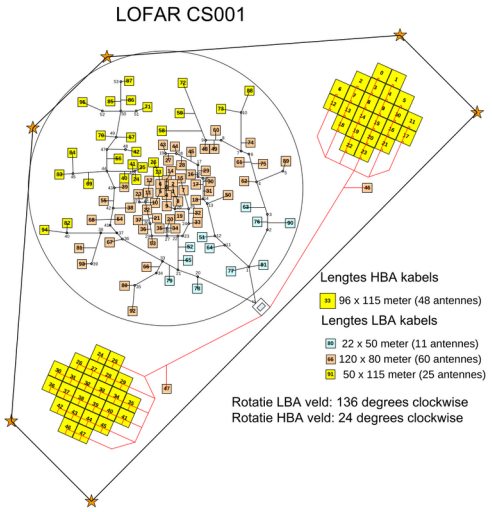
LOFAR 2.0 Test Station

Since July 2023:

- New receiver boards (RCUs)
- New FPGA boards (UniBoard)
- New FPGA firmware
- New power supply hardware
- New clock distribution (White Rabbit)
- New monitoring and control software





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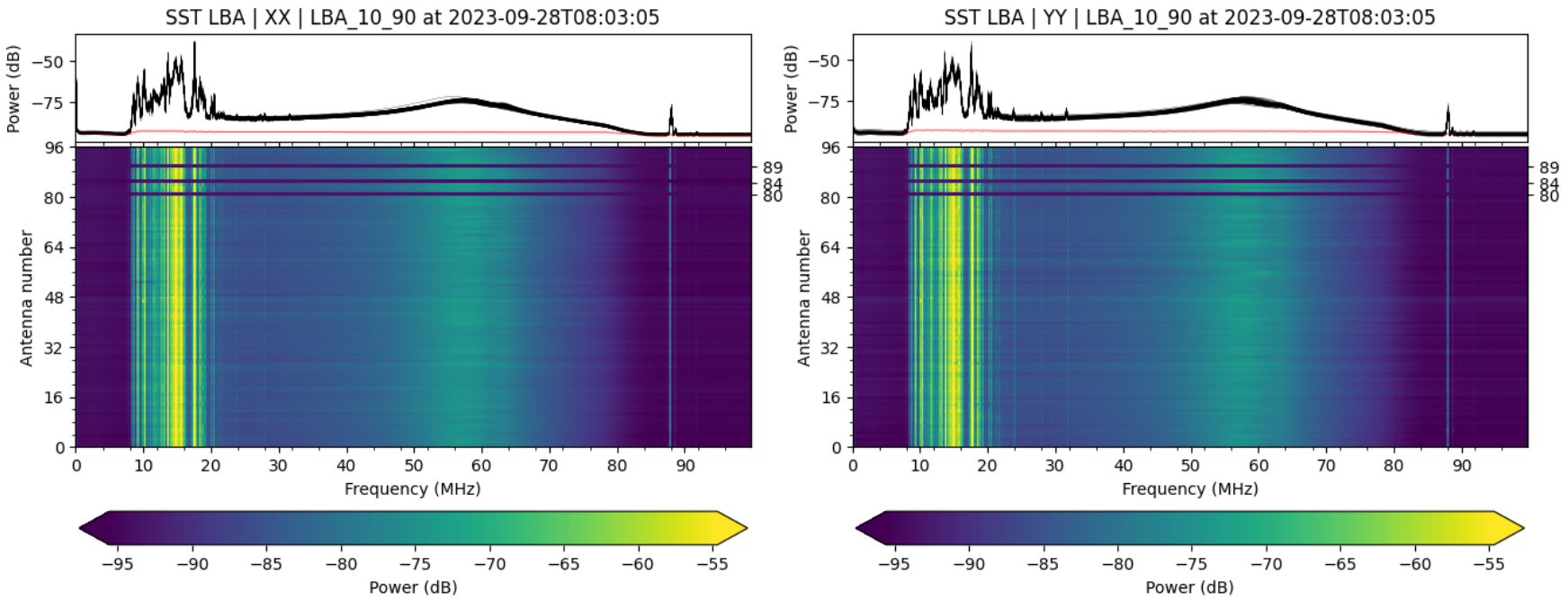
Subband statistics (SST)



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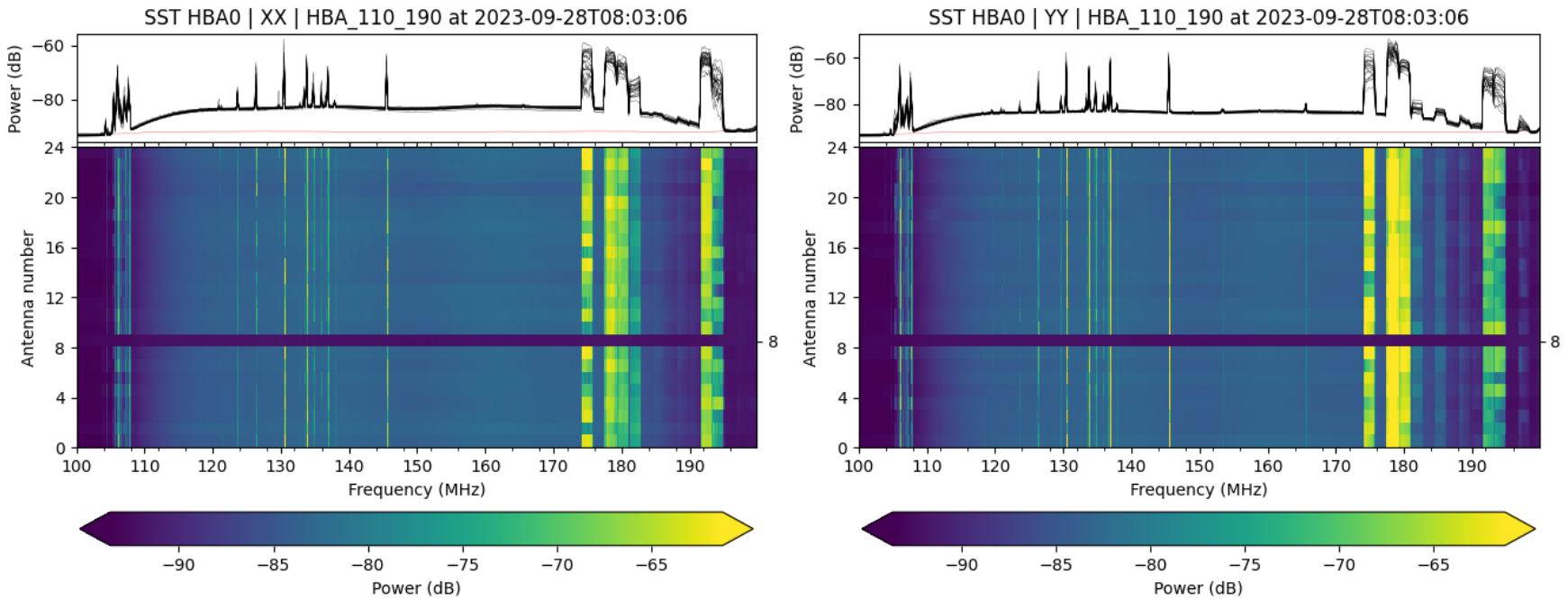

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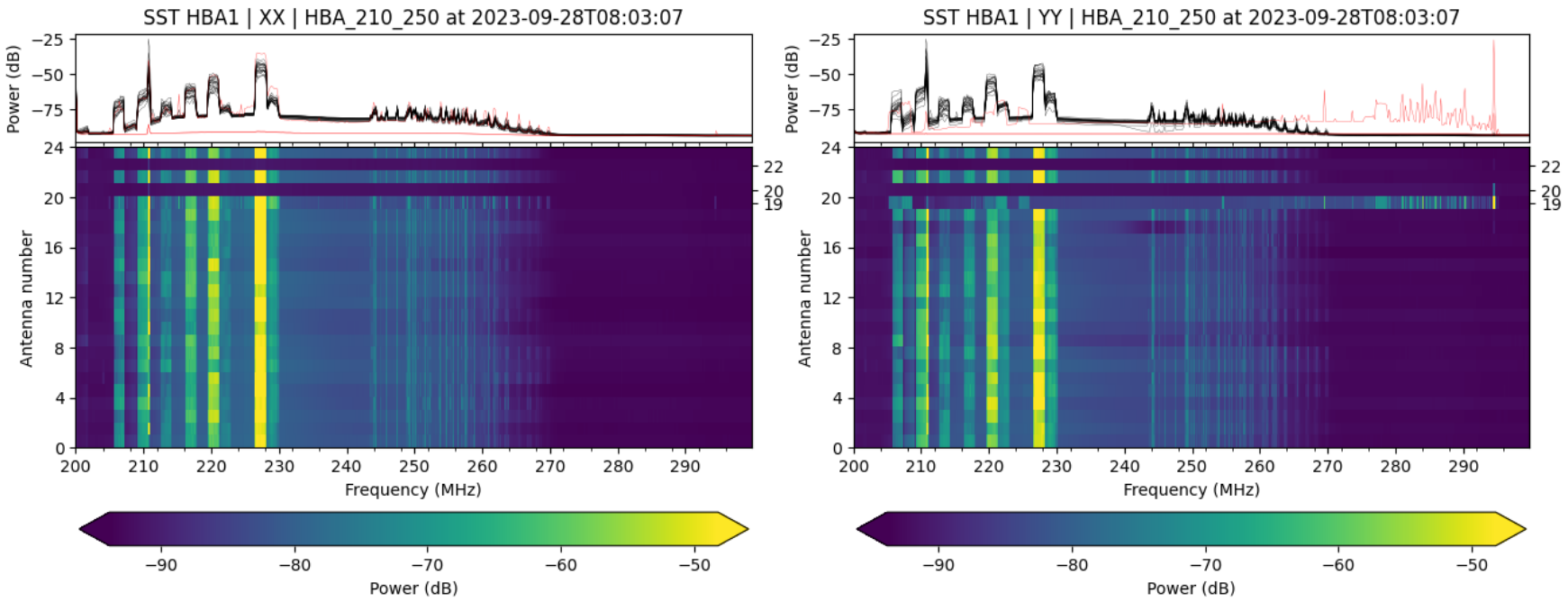
Subband statistics (SST)



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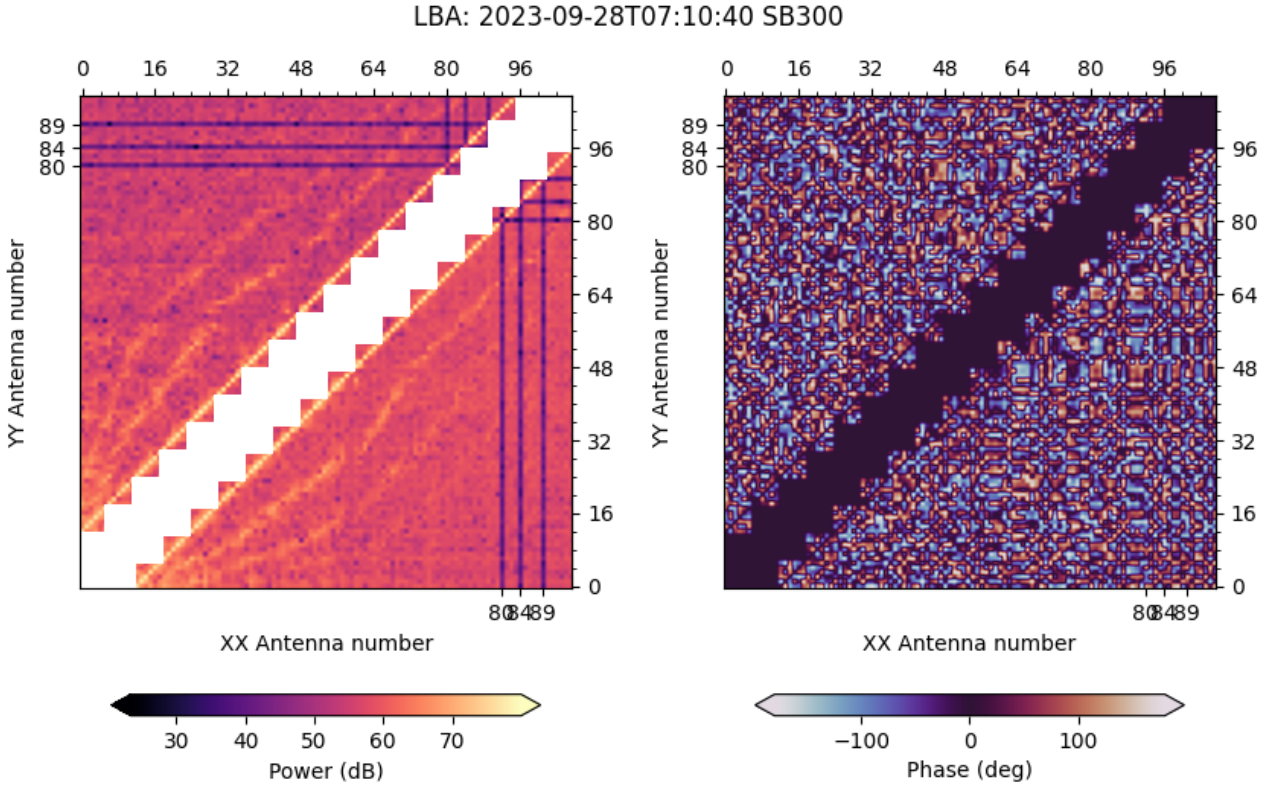
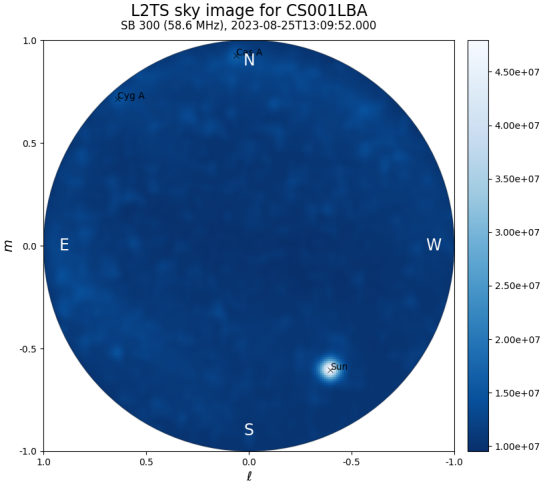
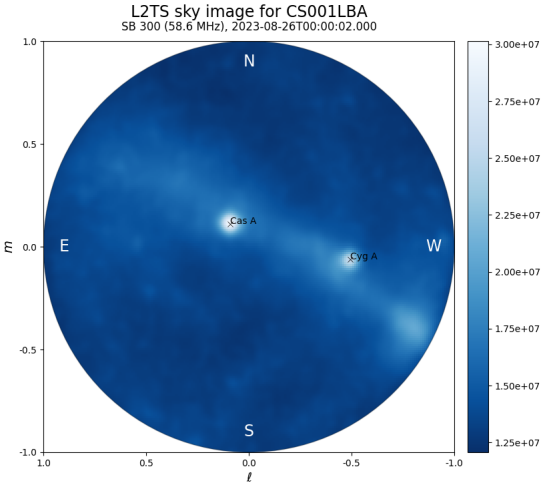
Crosslet statistics (XST)







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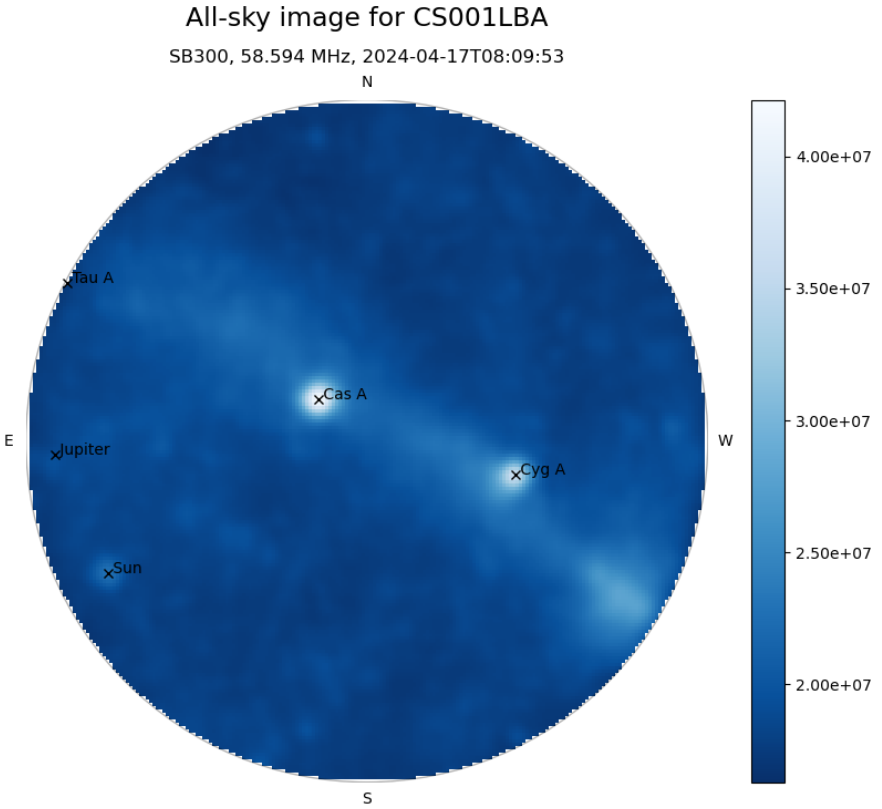
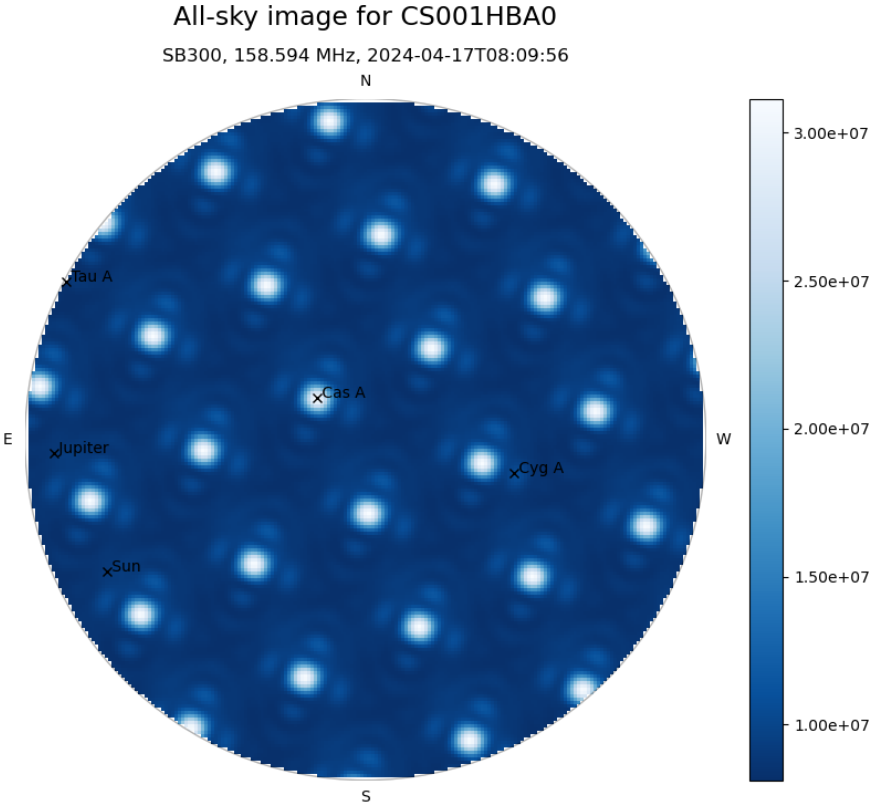
All sky images





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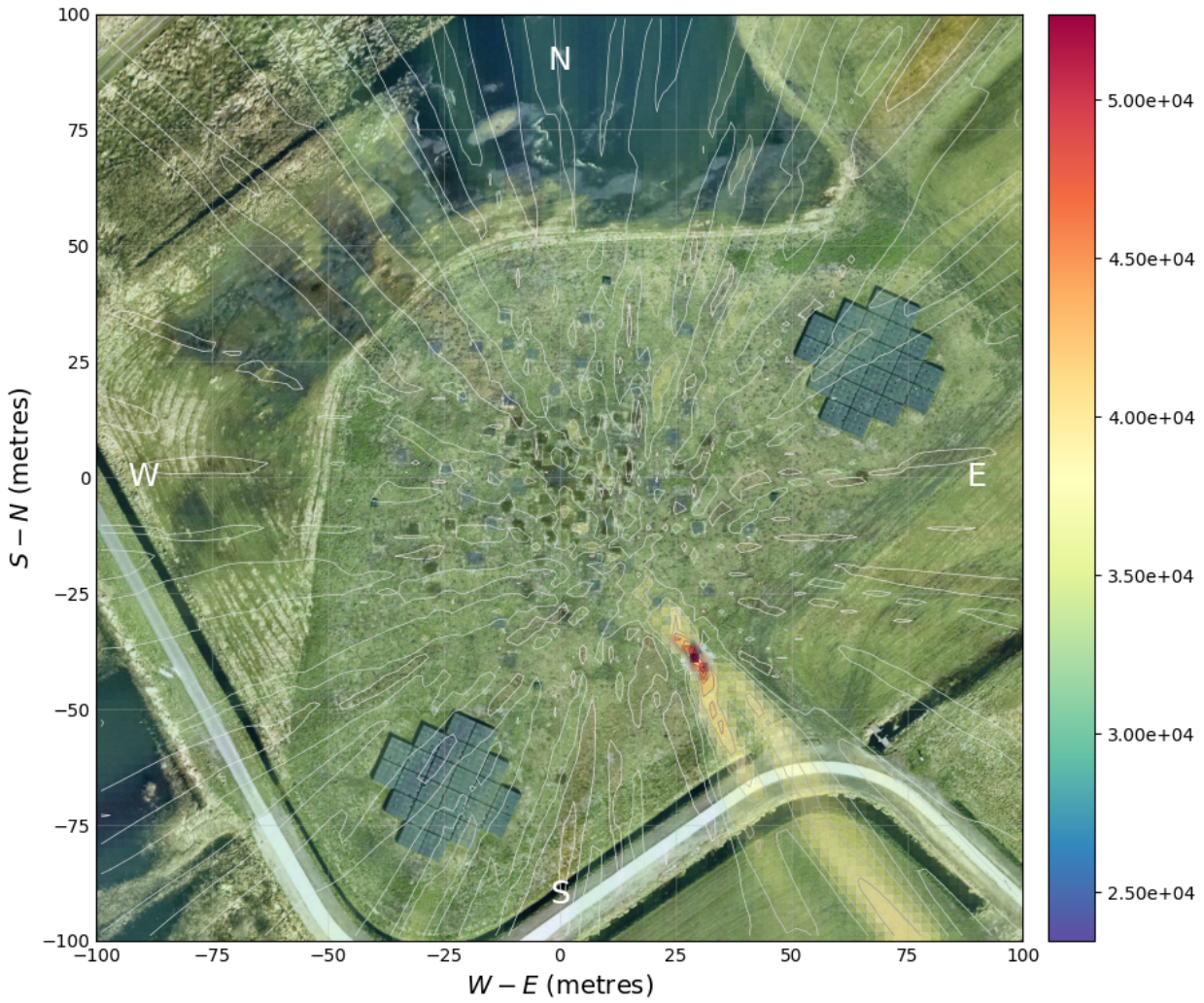

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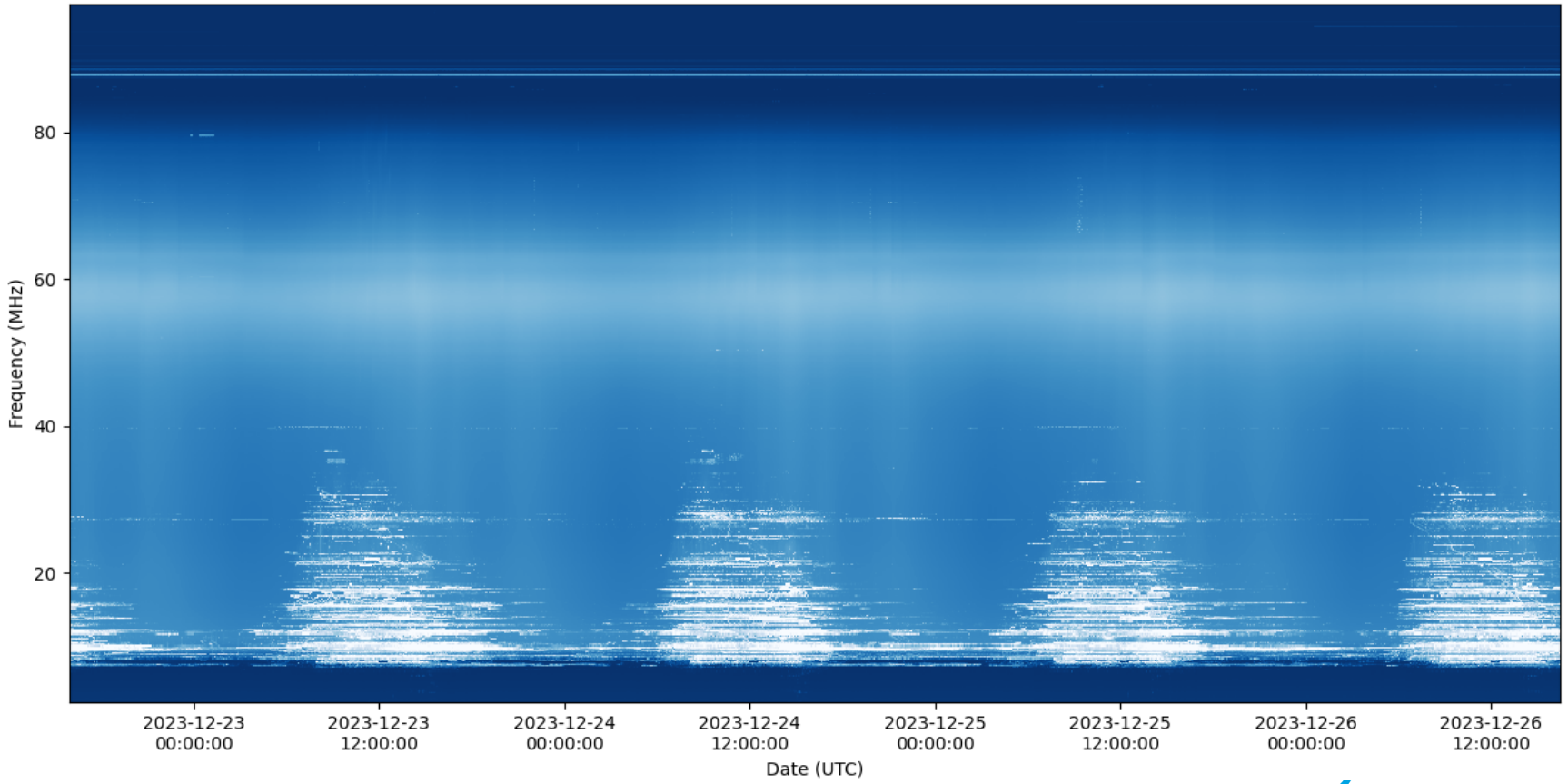
Beamlet statistics (BST)



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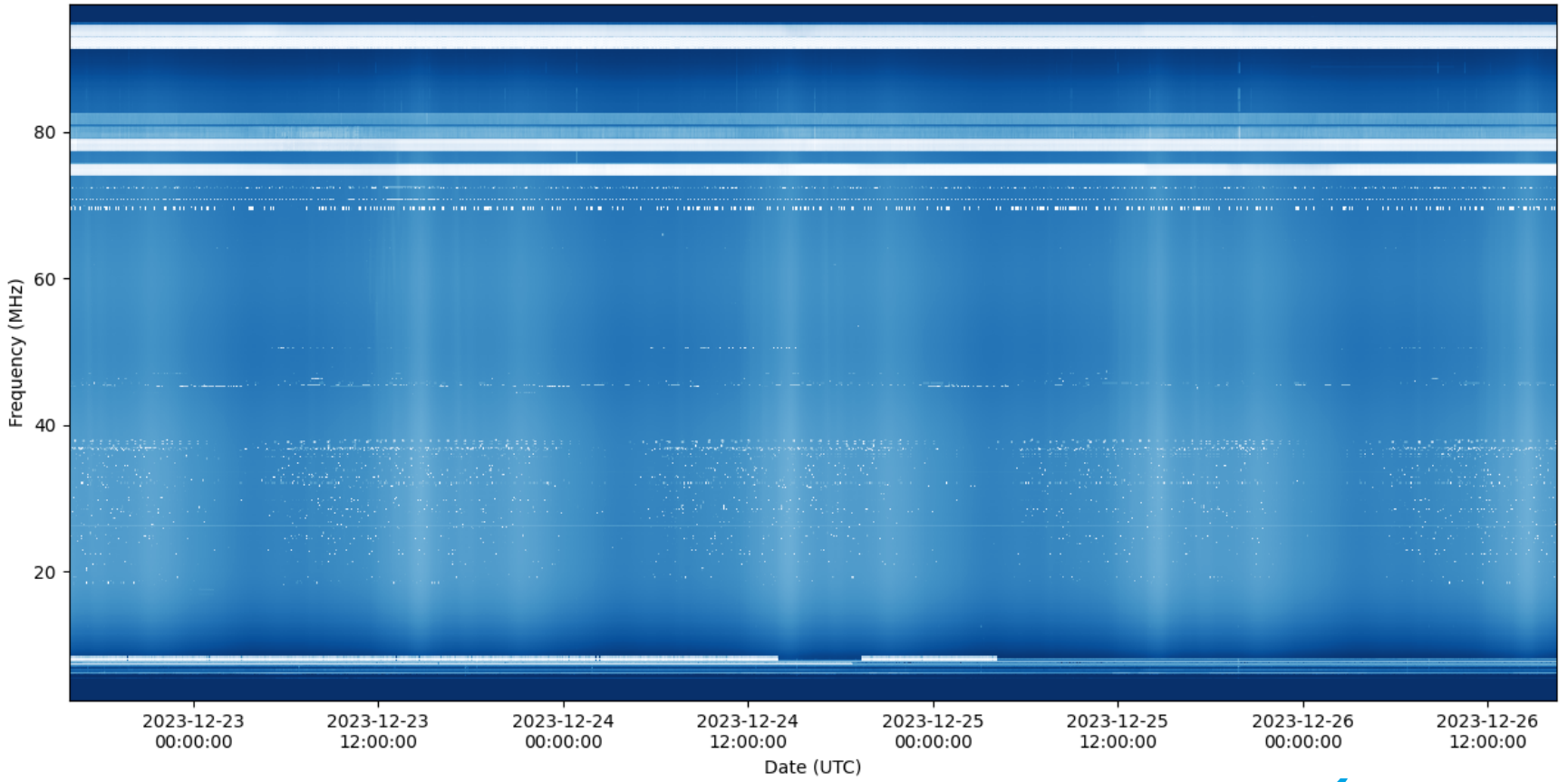
Beamlet statistics (BST)



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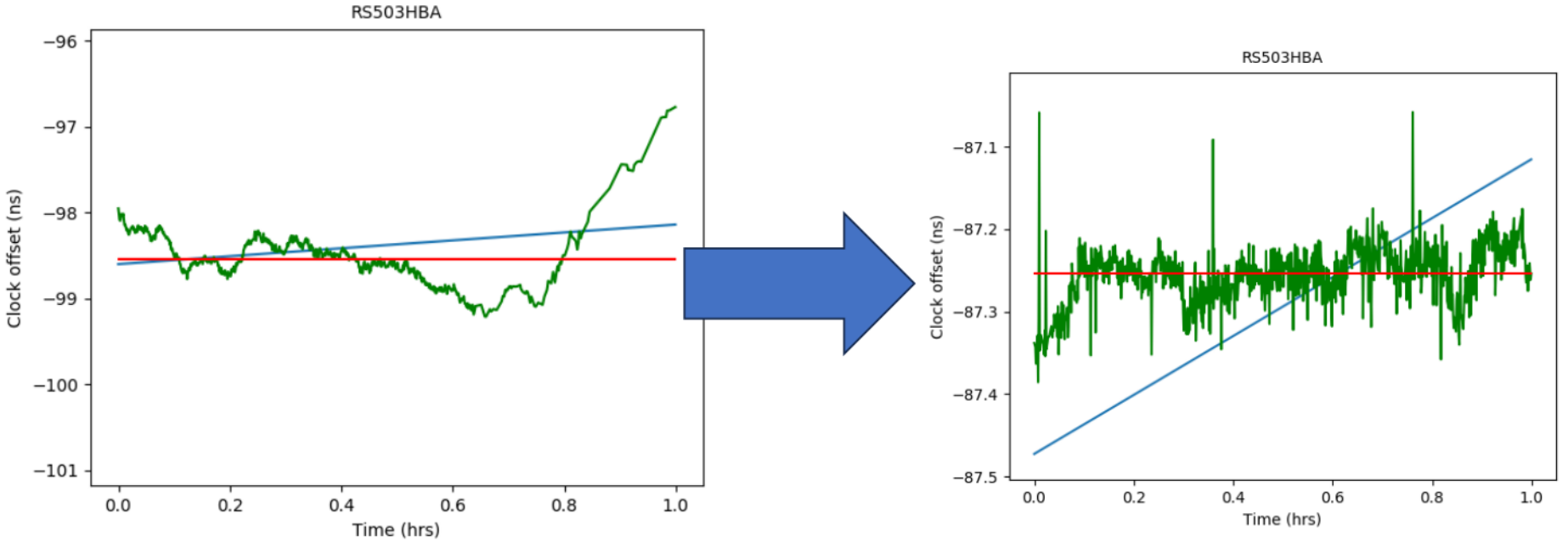
White Rabbit clock and frequency distribution

Already being rolled out to Dutch remote stations



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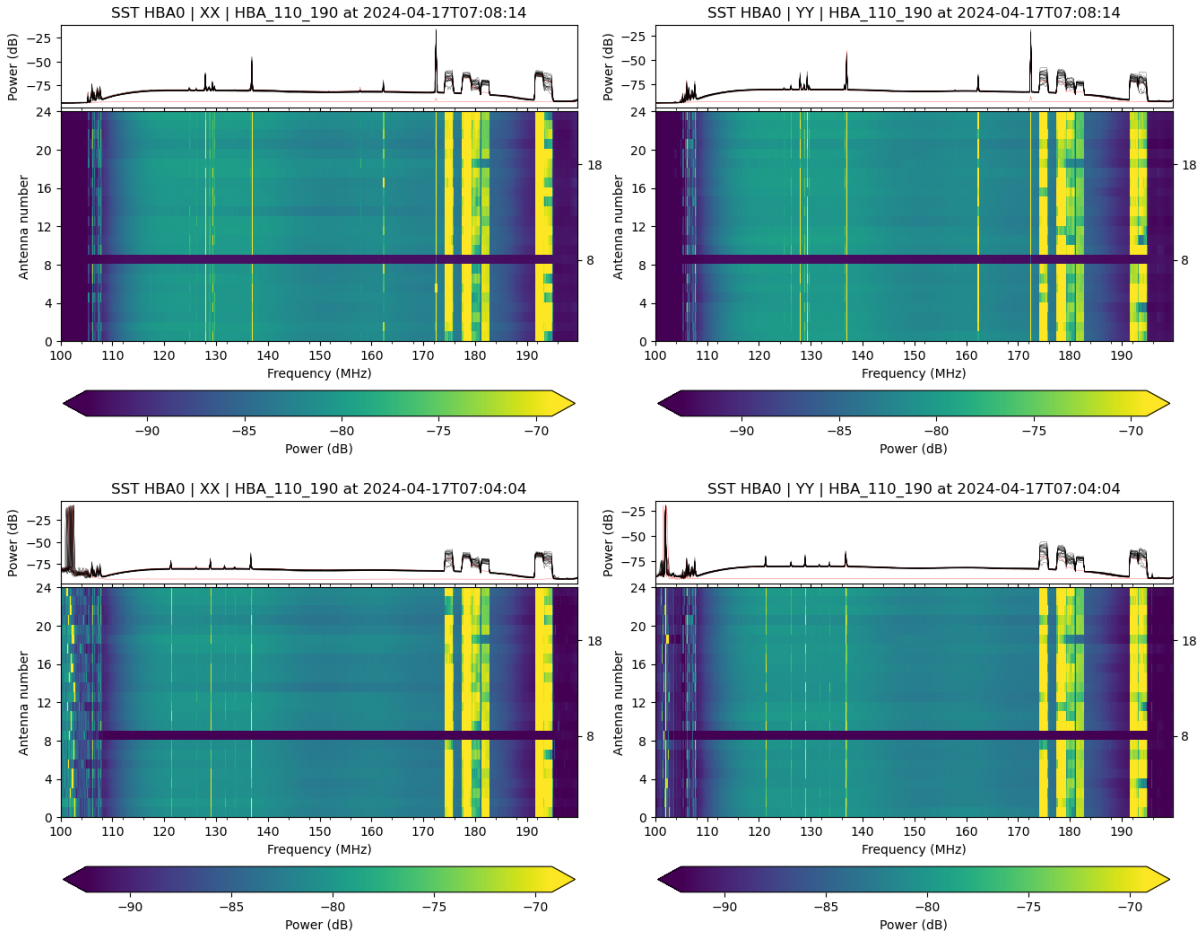
New and dropped functionality

New functionality:

- Single clock
- LBA_ALL
- LBA and HBA simultaneous
- DAB filter
- Dithering
- Meta data for statistics
- Improved linearity

Dropped functionality:

- HBA_JOINED antenna set
- 160MHz clock
- 16bit station data



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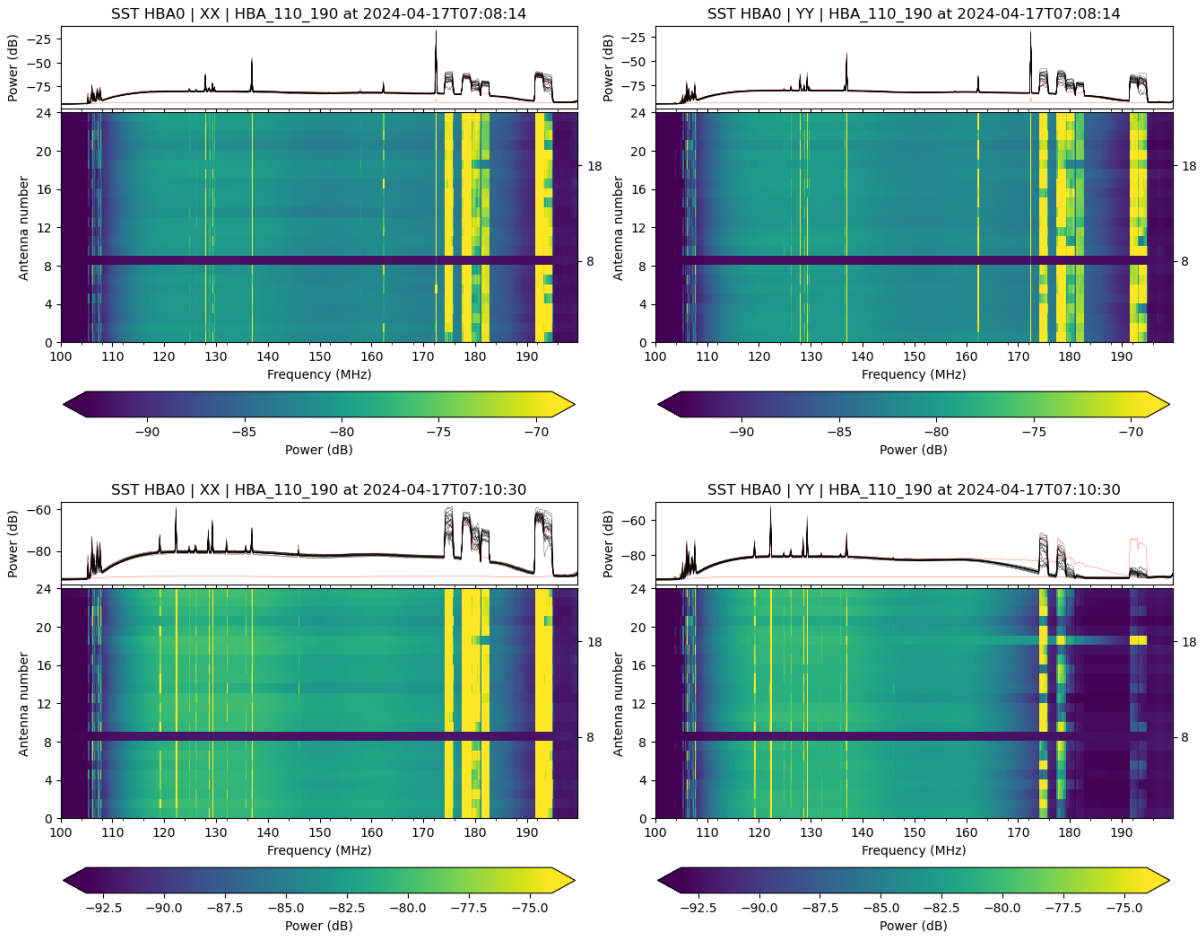
New functionality

- LBA_ALL
- LBA and HBA simultaneous
- DAB filter
- Dithering
- Meta data for statistics
- Improved linearity

Lost functionality:

- HBA_DUAL antenna set
- 160MHz clock



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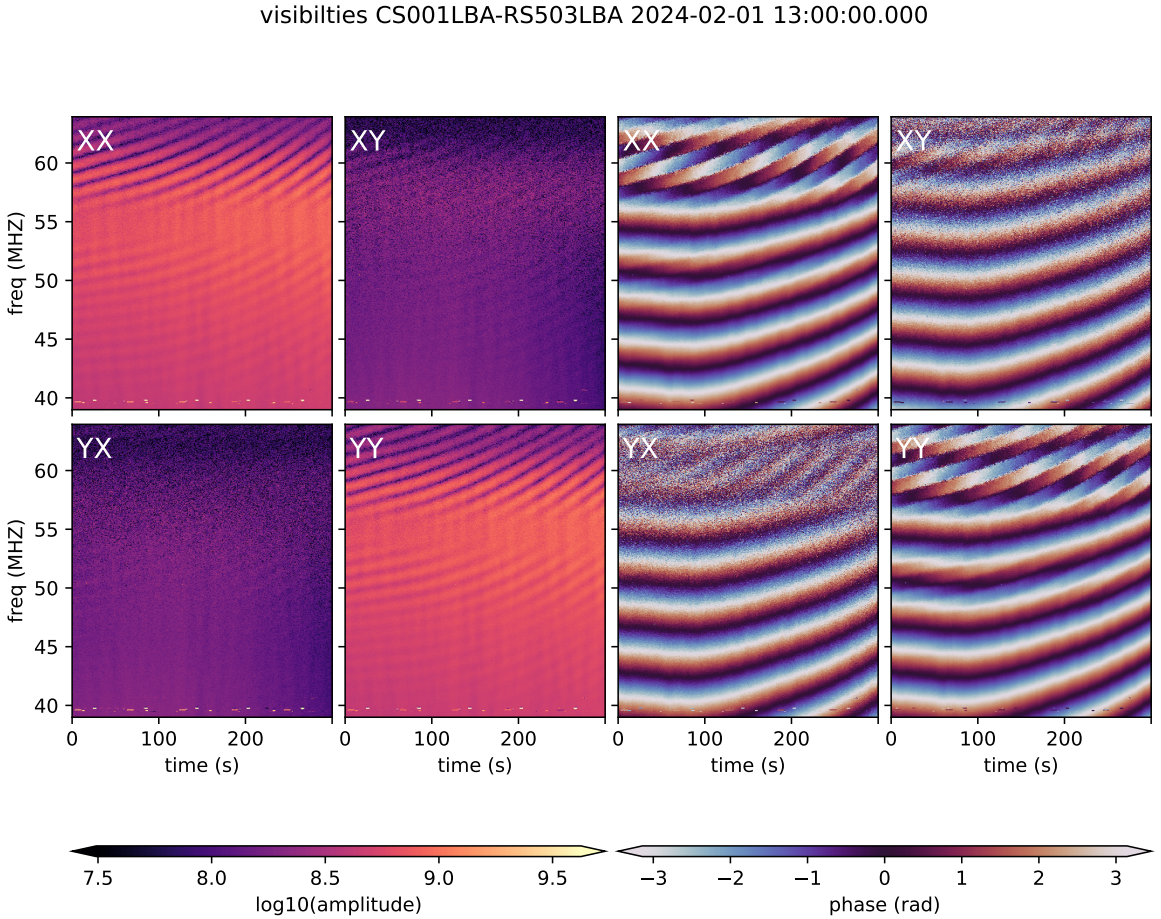
Station data to COBALT



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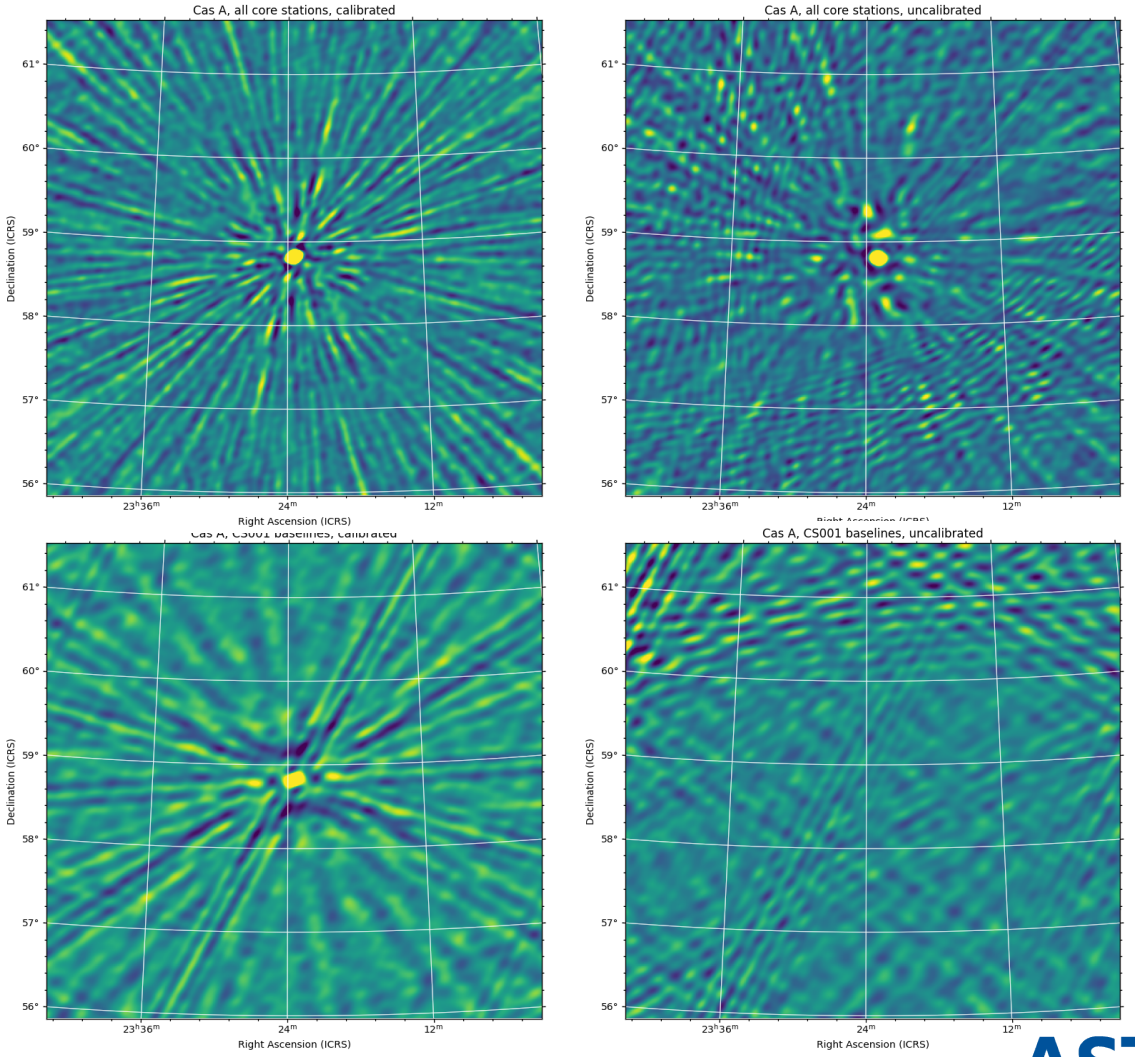

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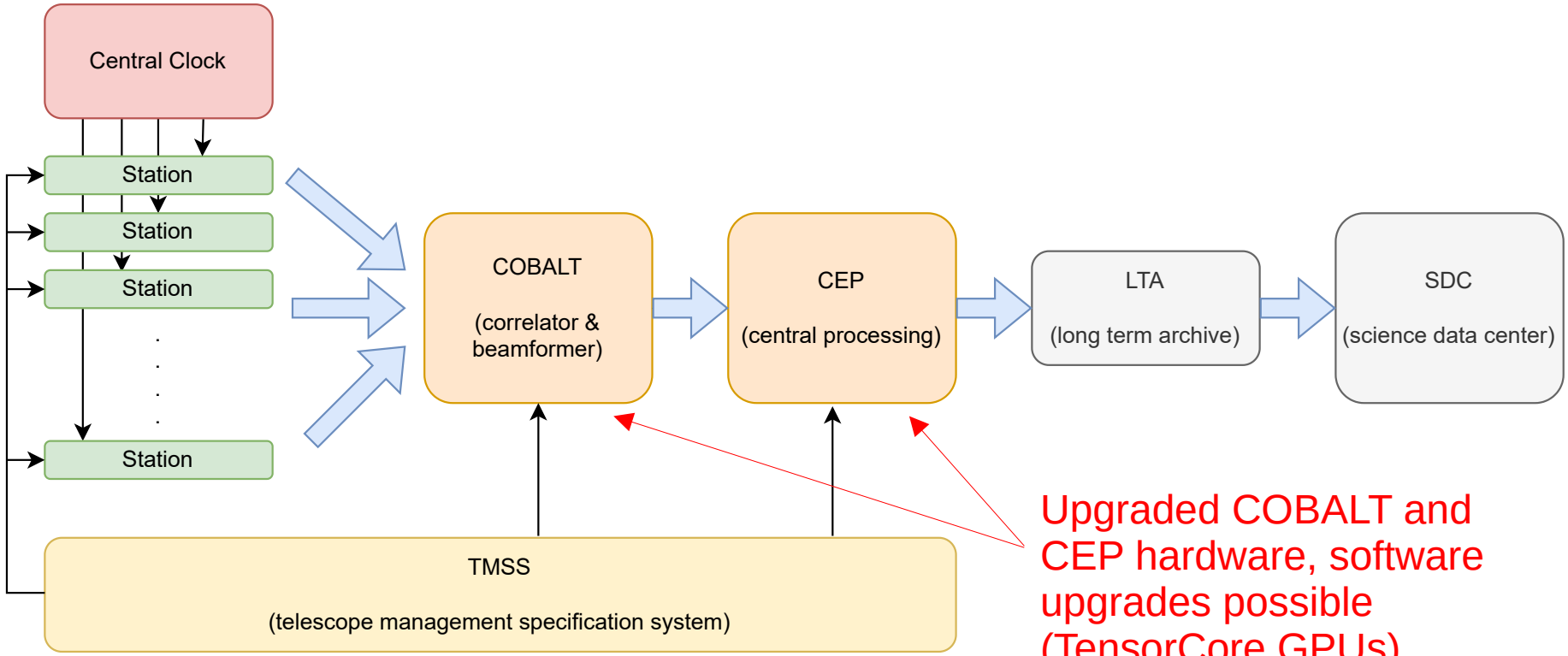
Upgrading COBALT, CEP and network



Upgraded COBALT and CEP hardware, software upgrades possible (TensorCore GPUs)

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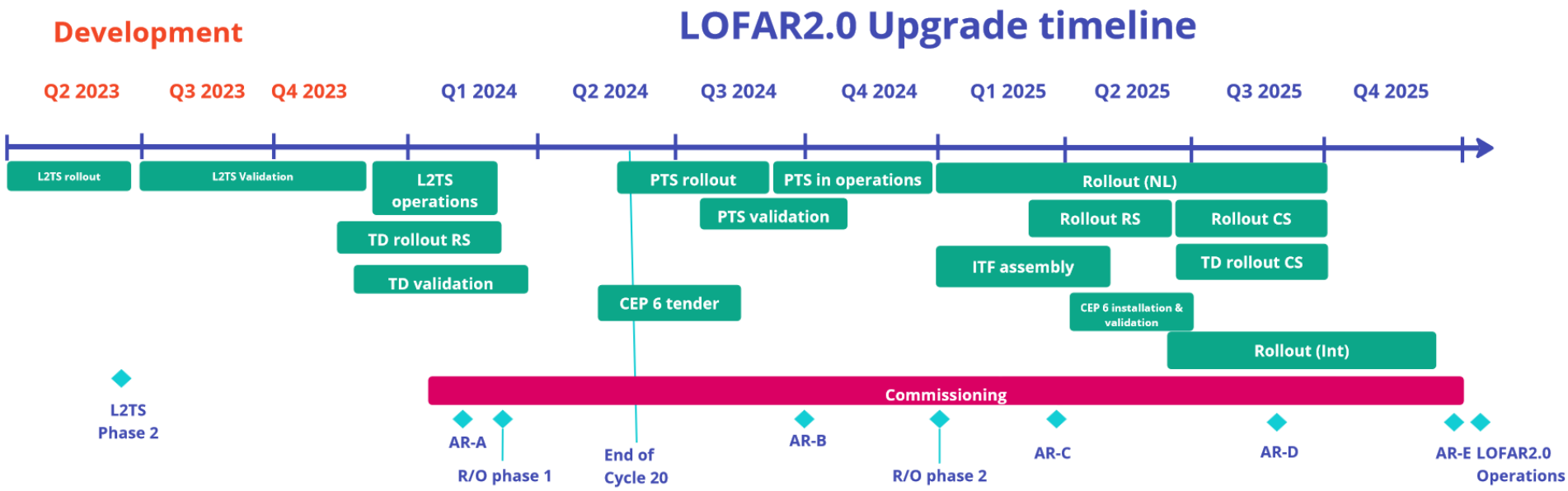
LOFAR2.0 planning



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What will change for you?

- Higher sensitivity for LBA observations with LBA_ALL
- Possibility of observing simultaneously with LBA and HBA
- More stable clocks and hence easier calibration
- Improved robustness against HBA intermodulation

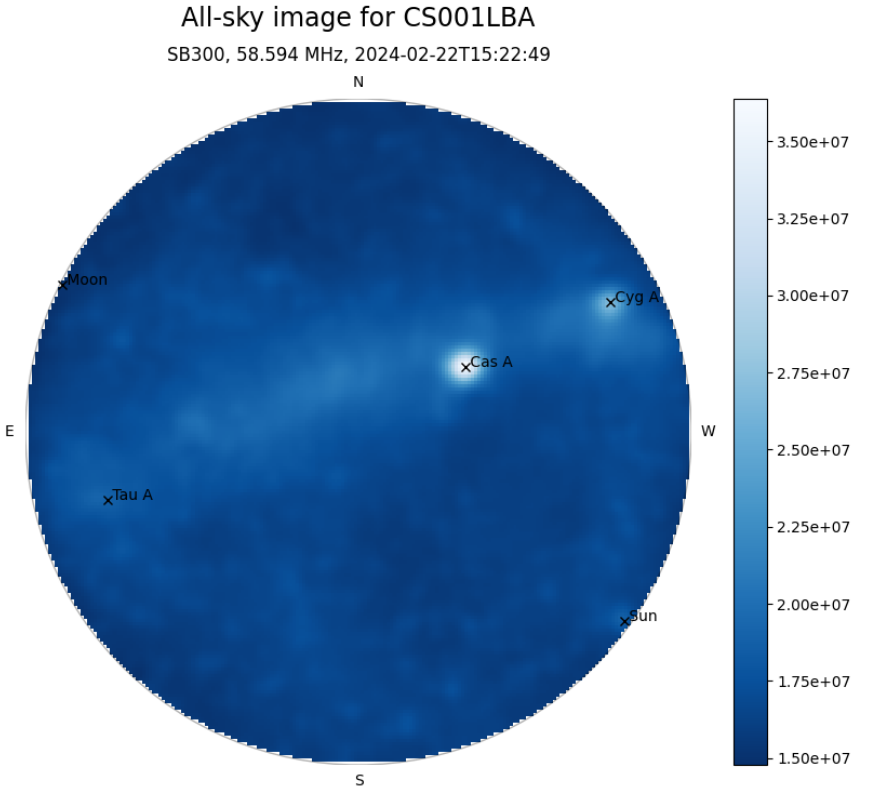
- Future expansion to allow more station beams
- Improved quality control due to better monitoring

Station calibration

Delays between antennas/tiles

1. Station visibilities against sky models
- Create sky models
- Use antenna/tile beam patterns
- Investigate impact of ionosphere
- Investigate accuracy
- Full Jones calibration?

2. Station holography
- Shown to work for HBA tiles
- Investigate/implement holography for LBA
- Enable station specification in TMSS



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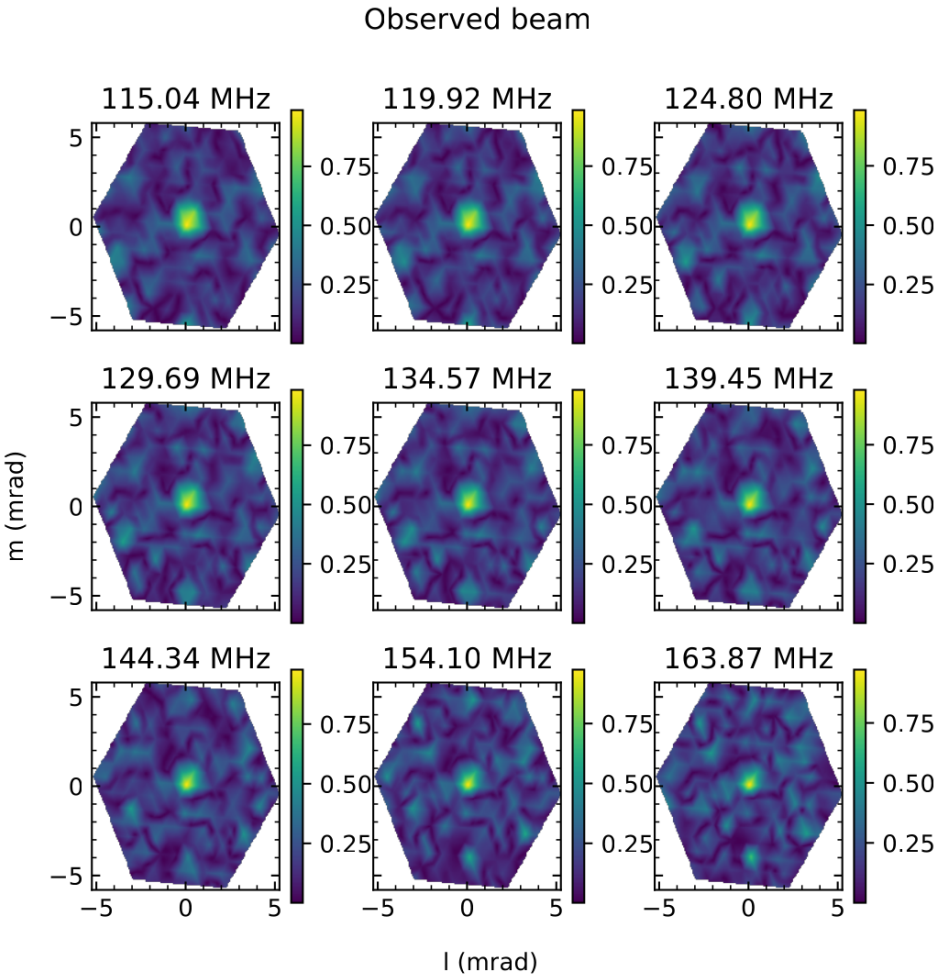
Array calibration

Delays between stations

1. Clock/TEC separation
- Works for HBA imaging observation
- Extend to LBA
- Validate with beamformer coherency

2. Tied-array holography
- Shown to work for LBA and HBA
- Test and improve algorithm
- Design TMSS strategy, make operational



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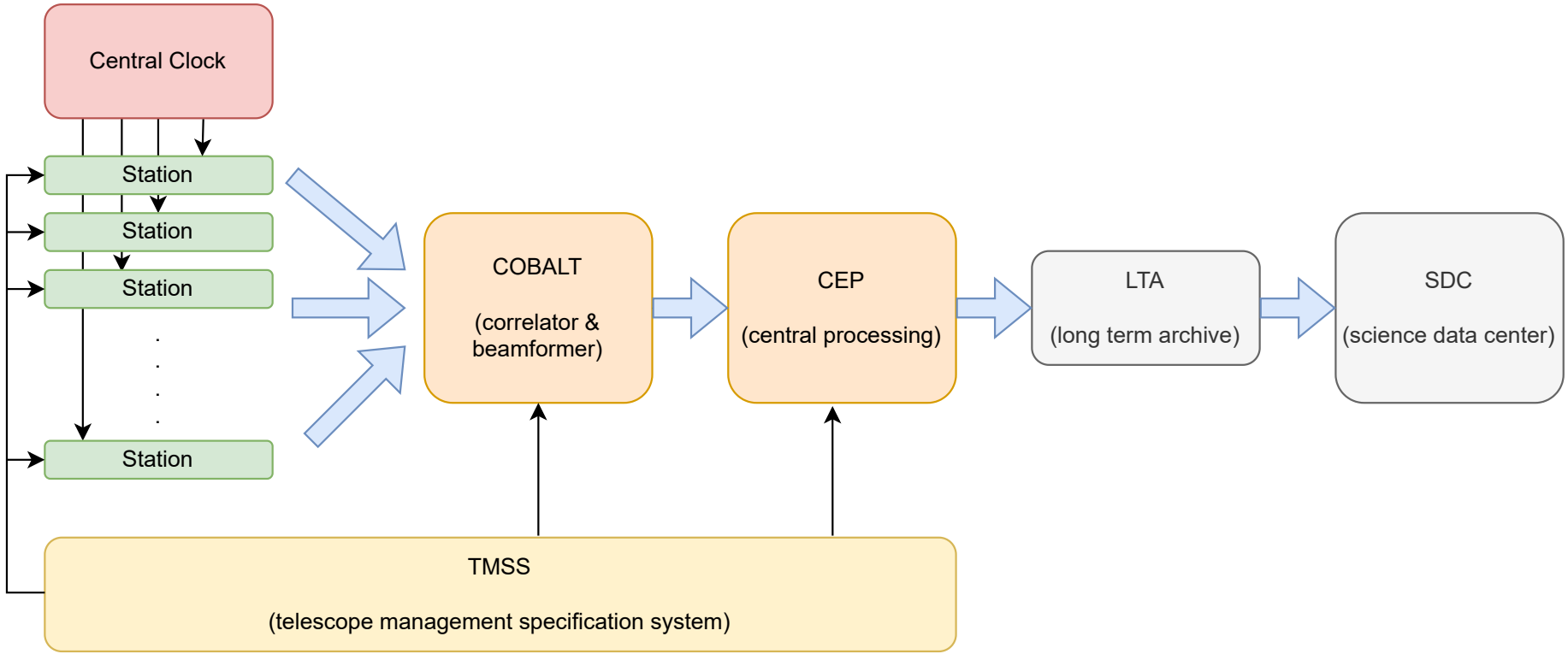
What is changing in LOFAR2.0?



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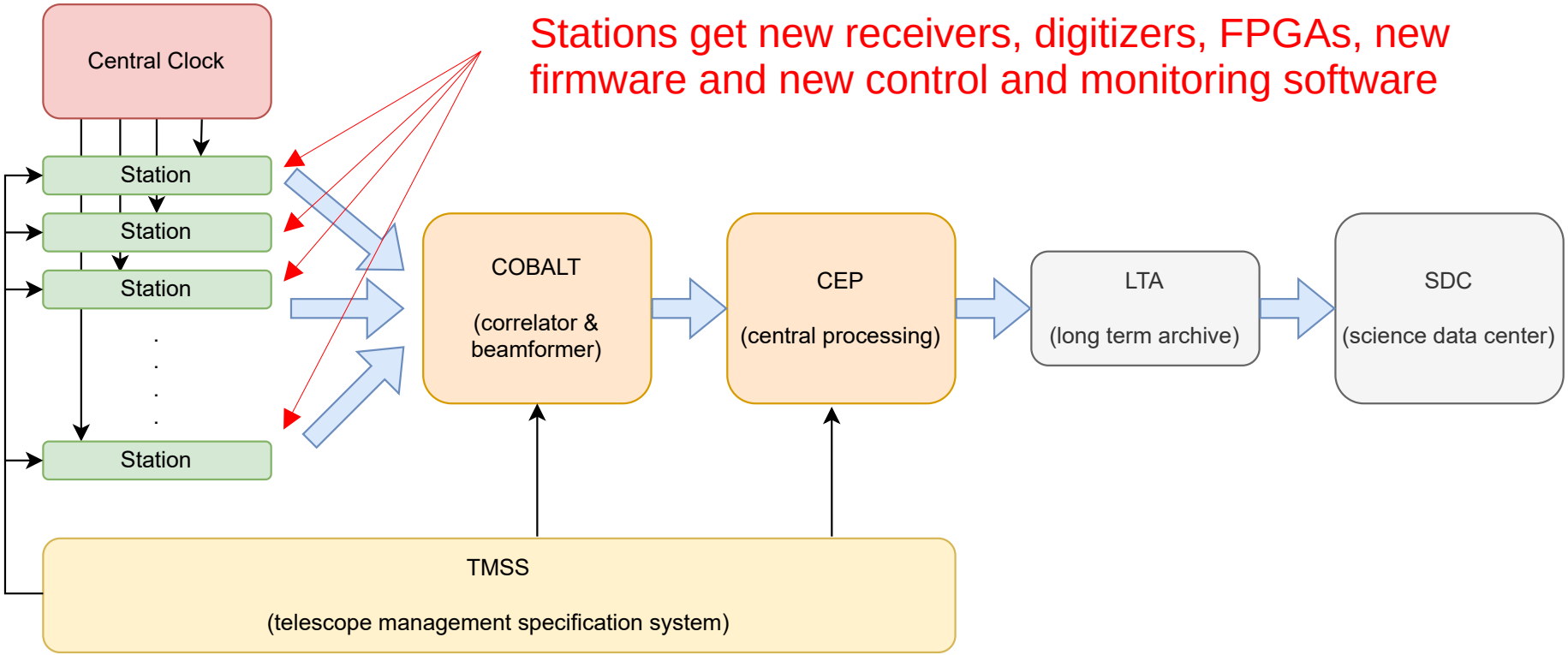

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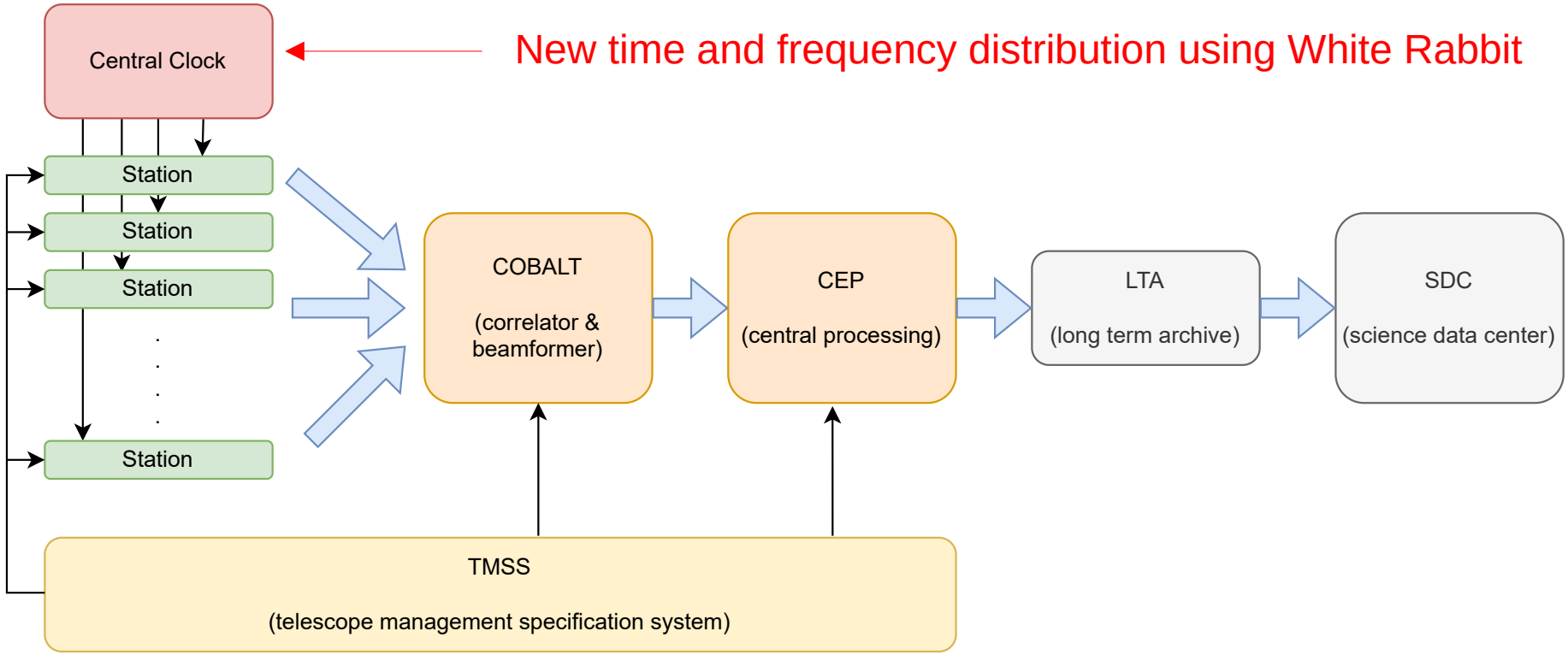

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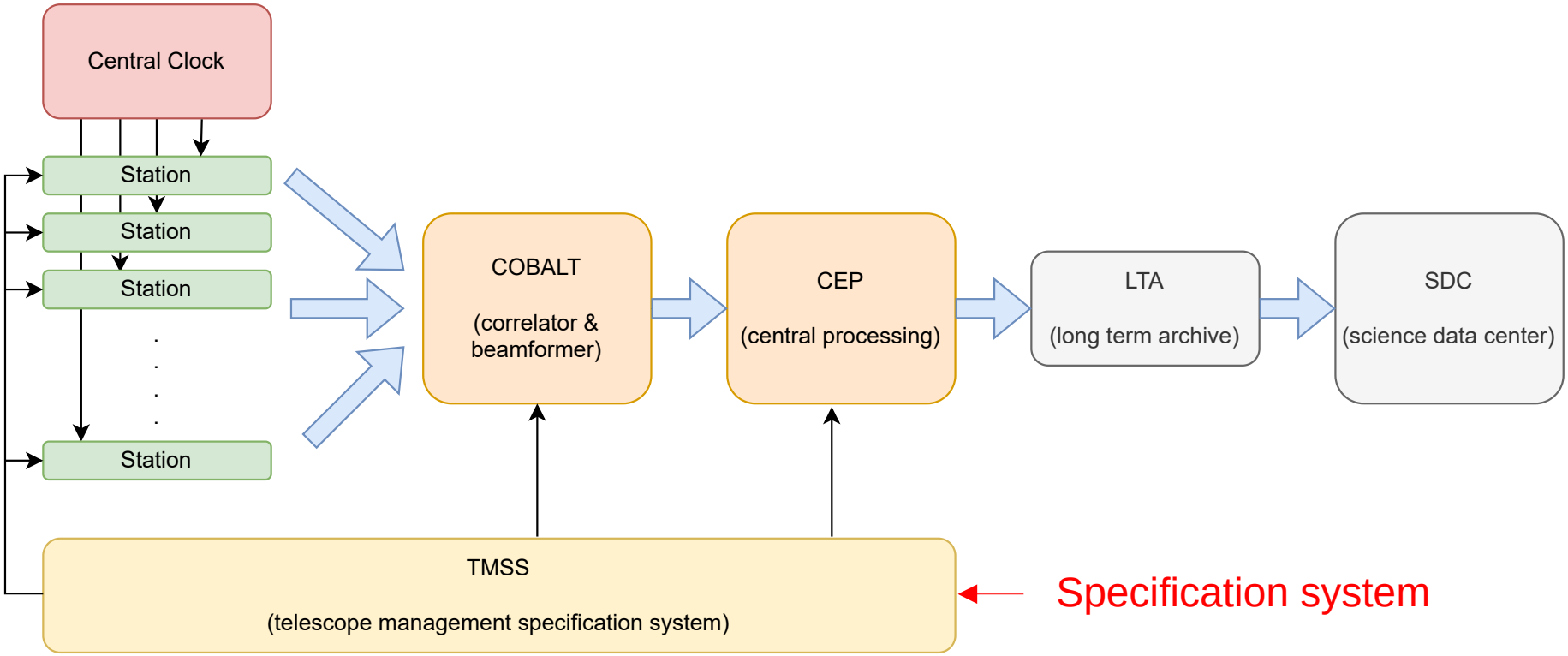

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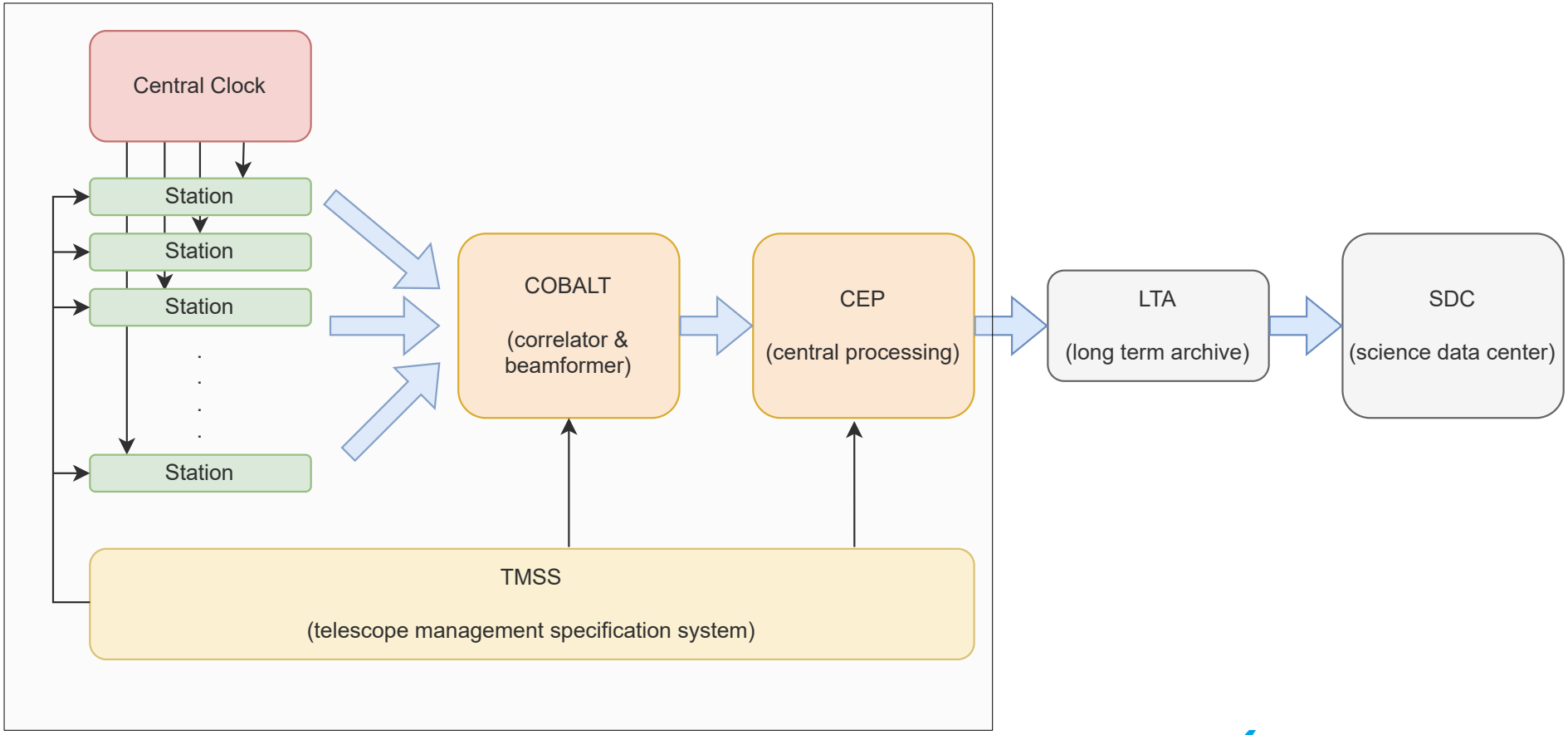

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