

LOFAR: the LOw Frequency ARray

Radio Observatory and R&D divisions
ASTRON, Dwingeloo, The Netherlands

LOFAR data school 2018

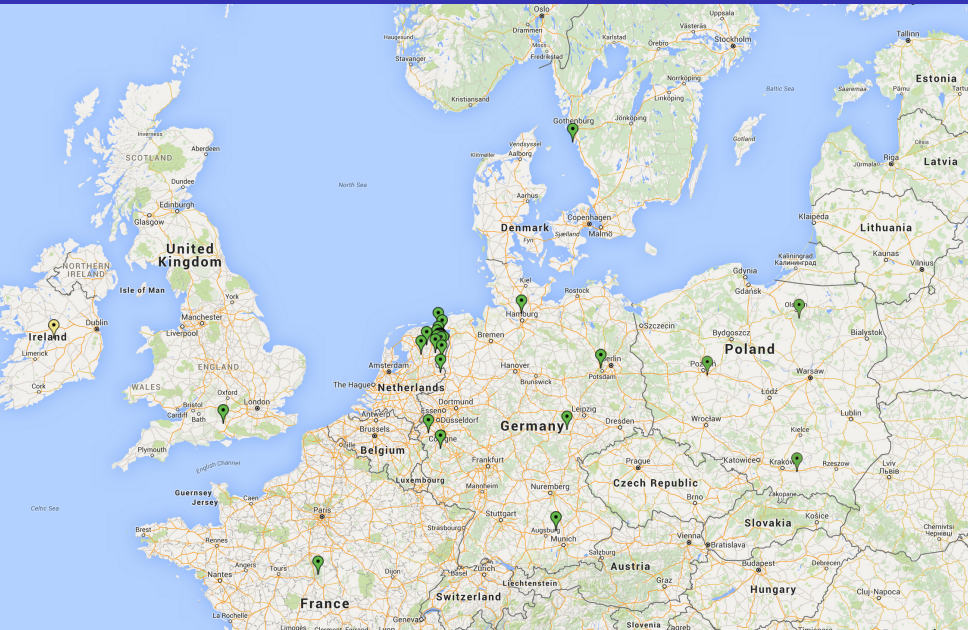
LOFAR: Lots Of Flimsy Antenna Rigs

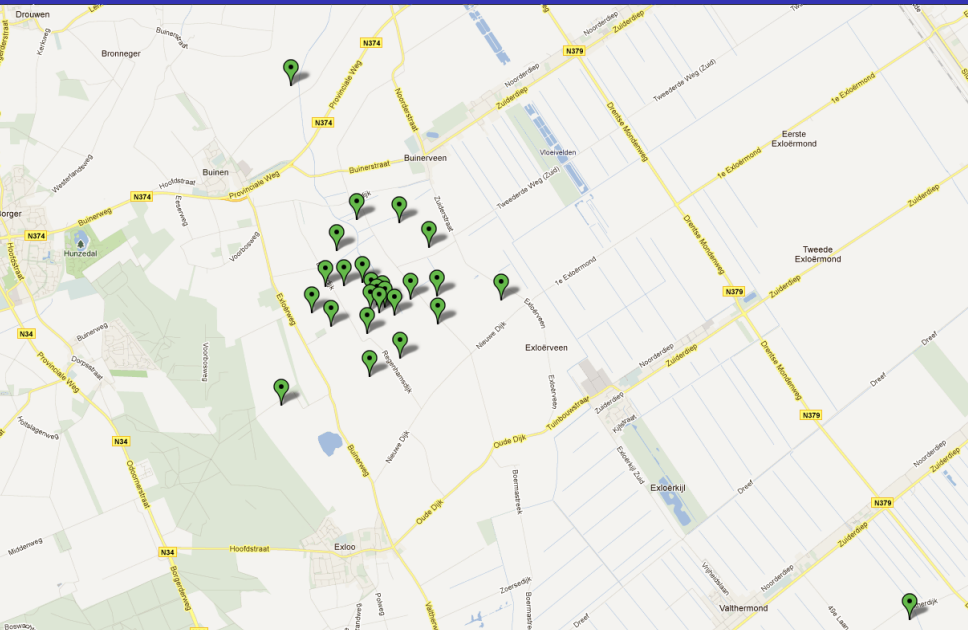
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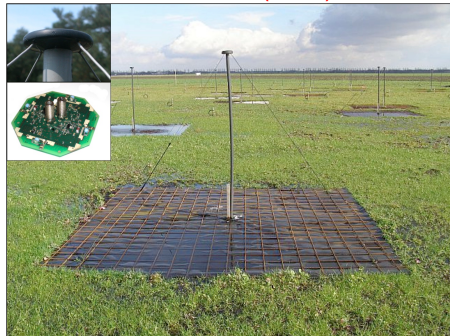
- 1 Architecture
- 2 Stations
- 3 SHORT BREAK
- 4 Central processing
- 5 Beams, beams, beams...
- 6 More beams...
- 7 If all goes well

A BIG radio telescope





Low Band Antenna (LBA)

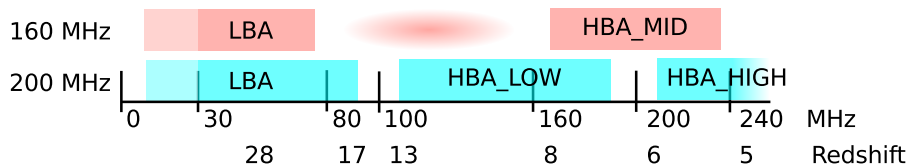


- 10–90 MHz
- All digital beam forming

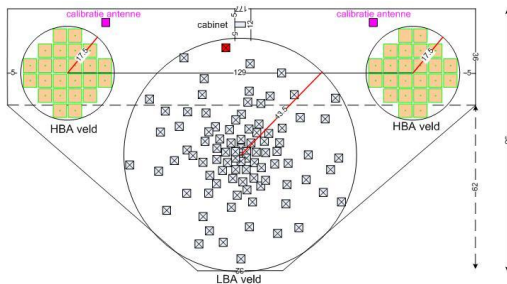
High Band Antenna (HBA)



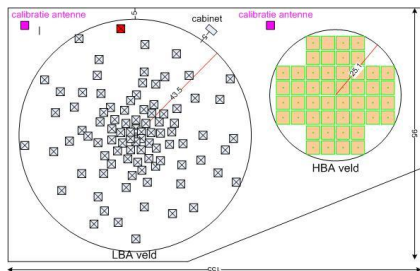
- 110–240 MHz
- 4x4 antennas per analogously beam formed tile
- Tiles beam formed digitally



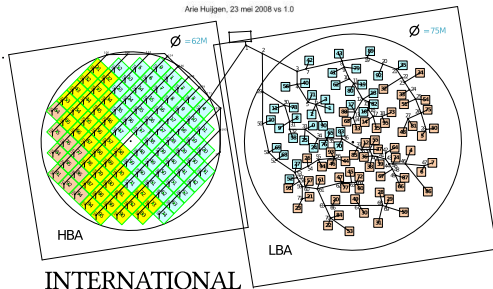
CORE

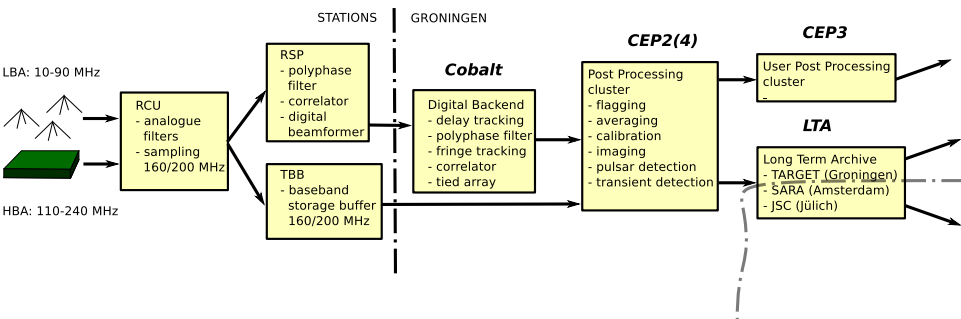
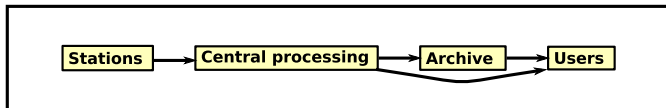


REMOTE

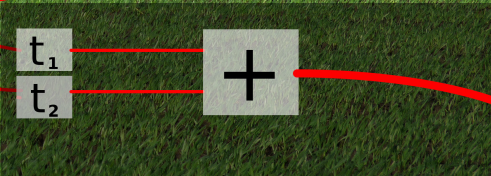
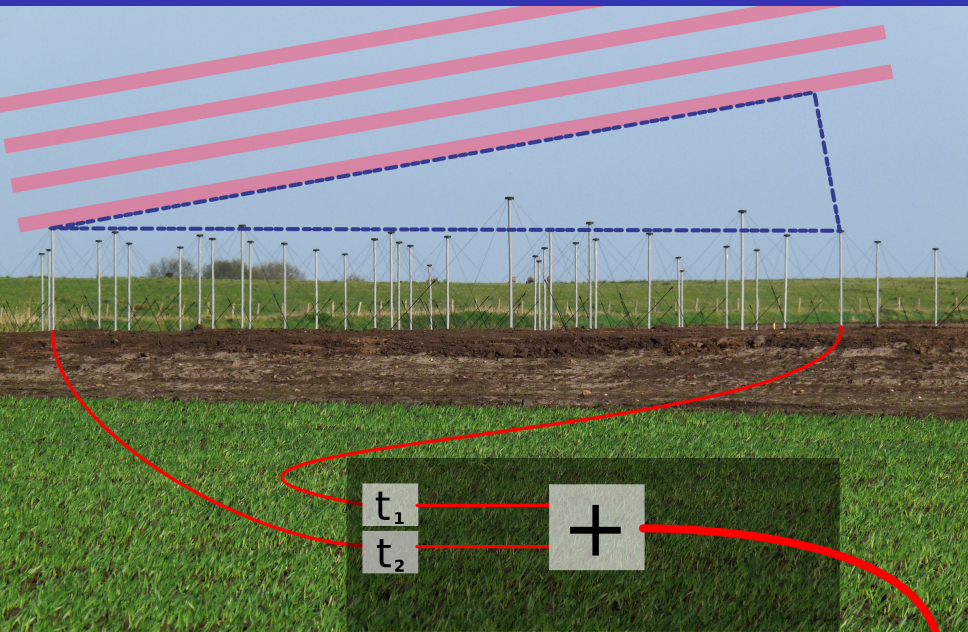


Arie Huijgen, 23 mei 2008 vs 1.0

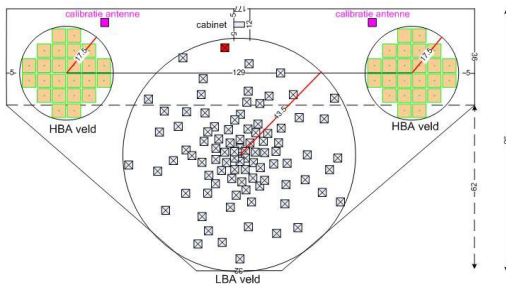




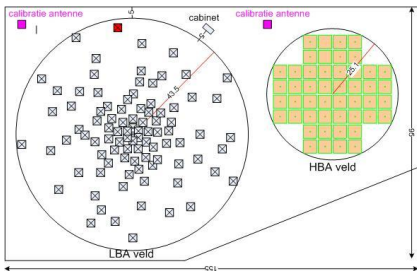
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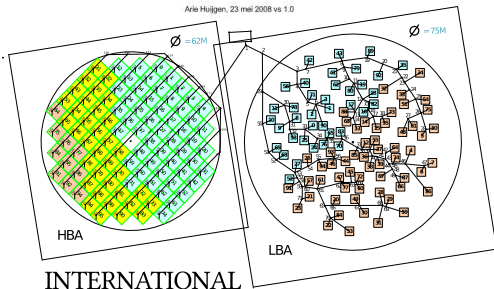
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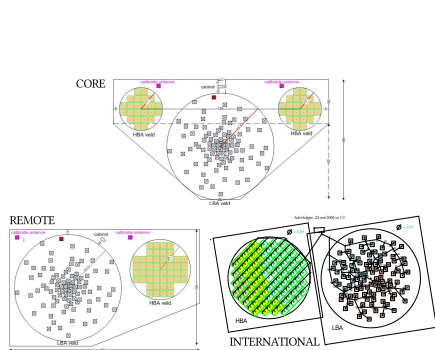
REMOTE



Arie Huijgen, 23 mei 2008 vs 1.0



INTERNATIONAL

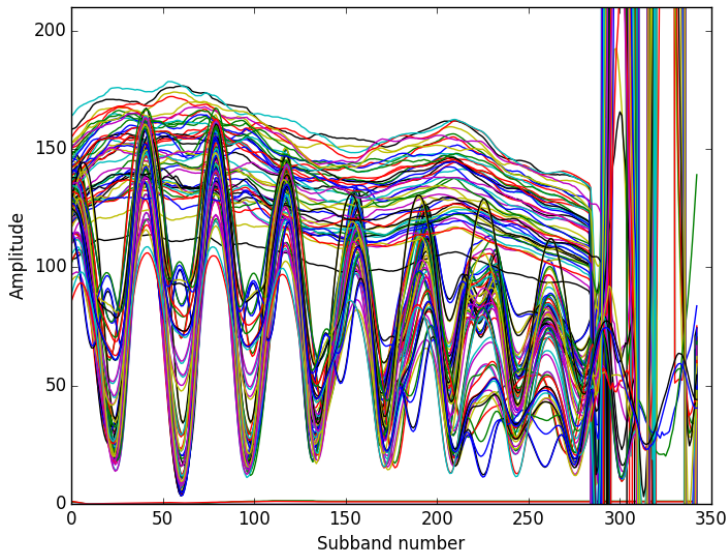


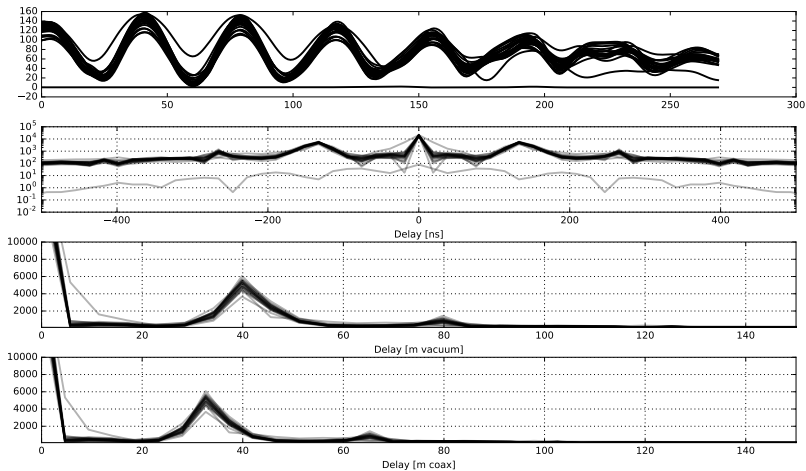
Possible cable lengths

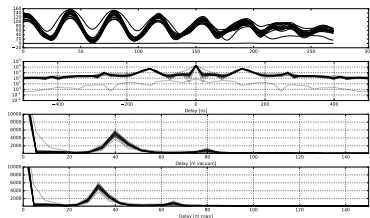
Velocity factor ~ 0.82

Length (m)	Appr. delay (ns)
50	199
80	327
85	343
115	466
130	531

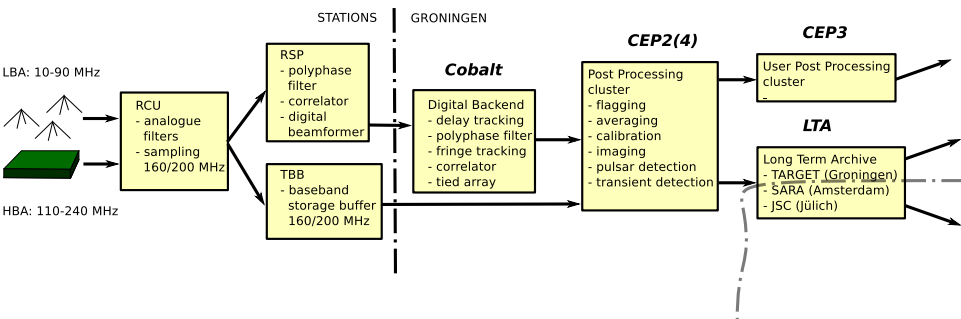
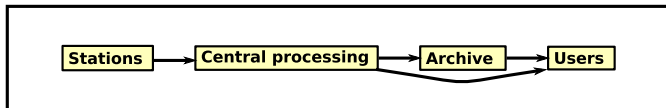
Compensated in Receiver Units
after digitization.

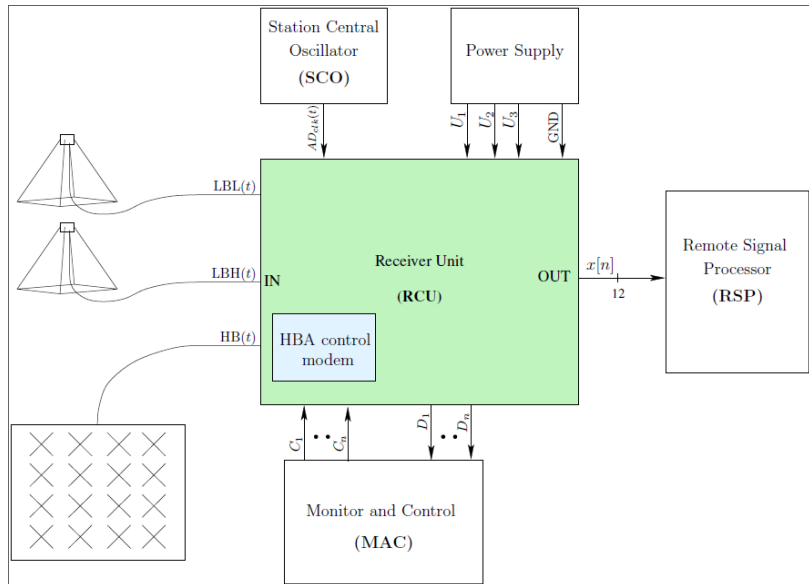


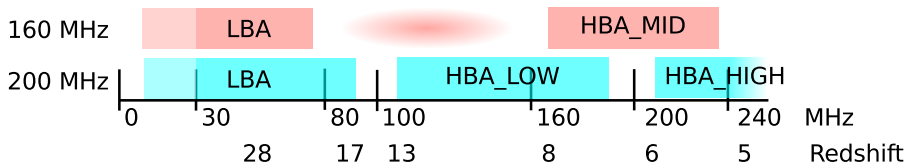
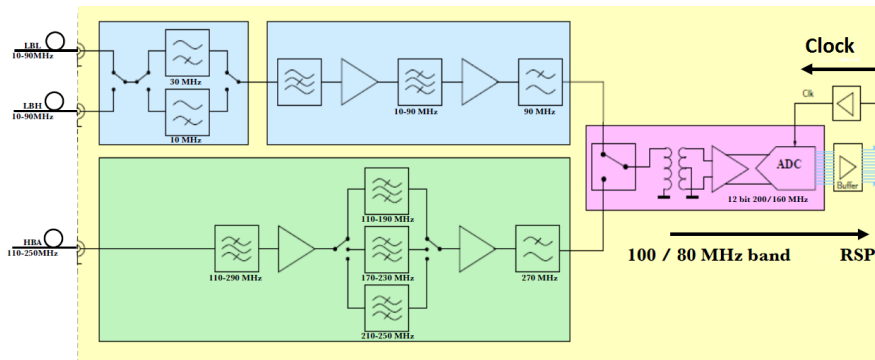


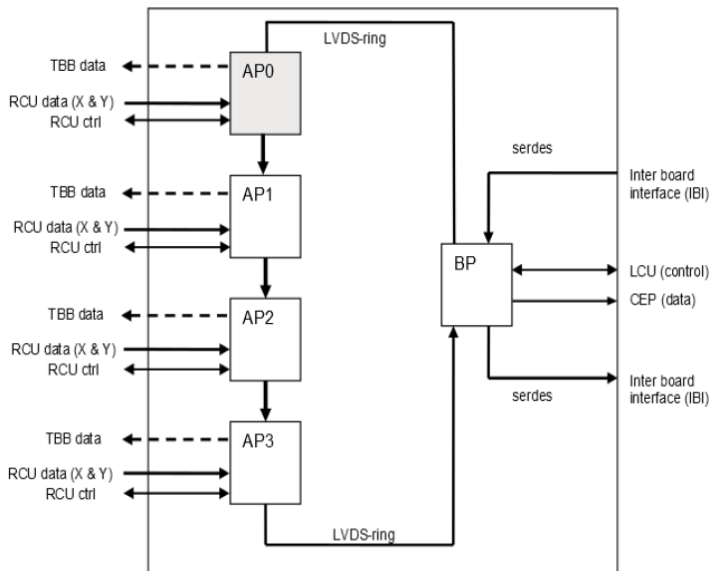


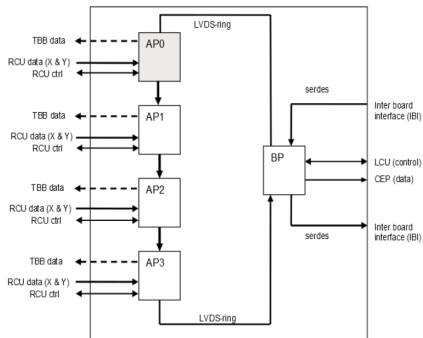
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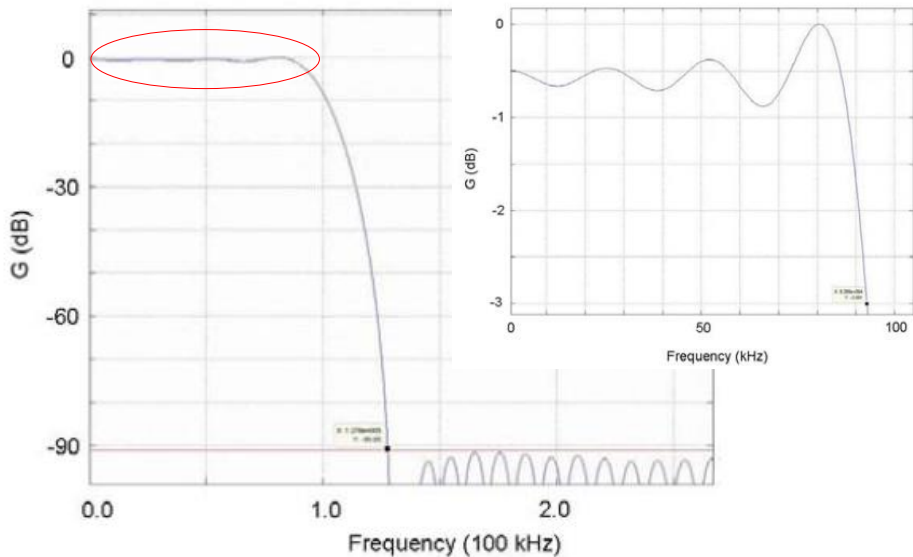


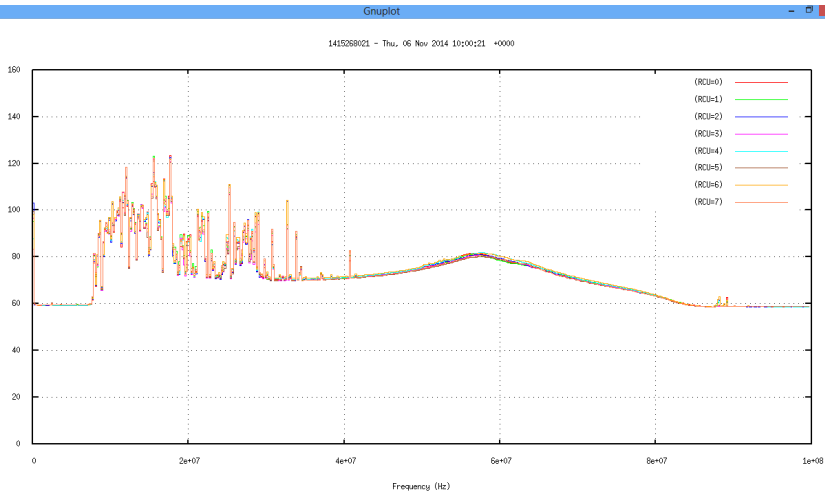




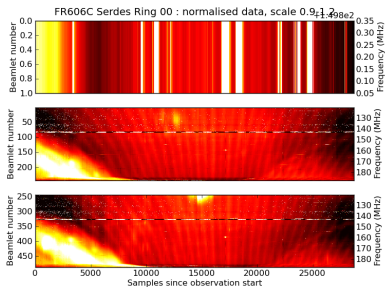
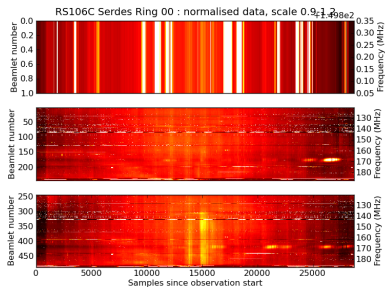
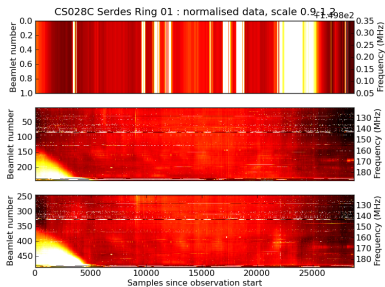
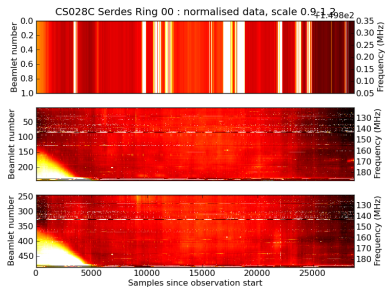


- Make 512 sub bands (polyphase filter)
- Beam forming
- Cross correlation
- Data transport to Central Processing

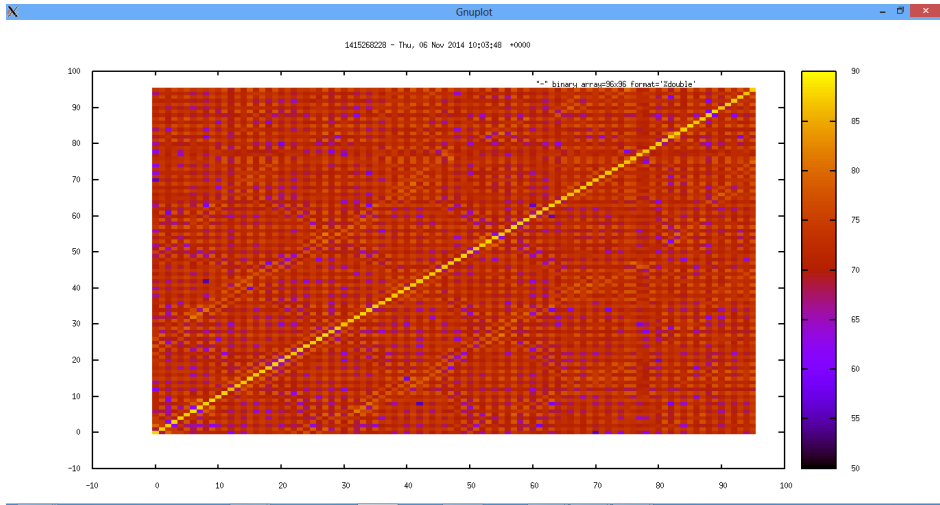


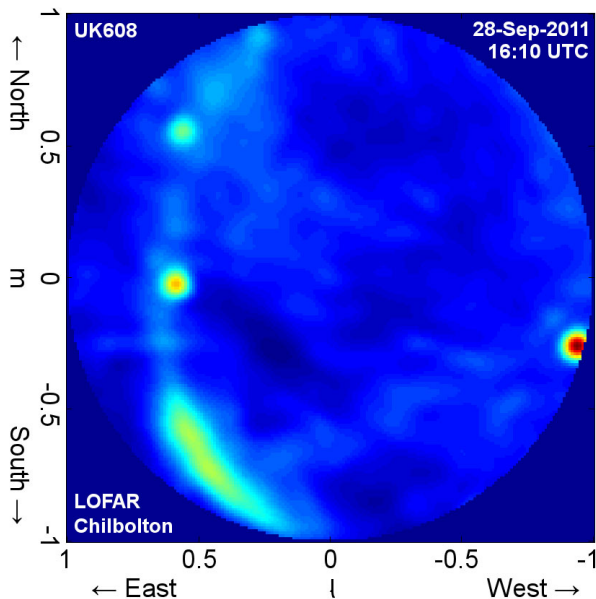


5.46947e+07, -26.0900





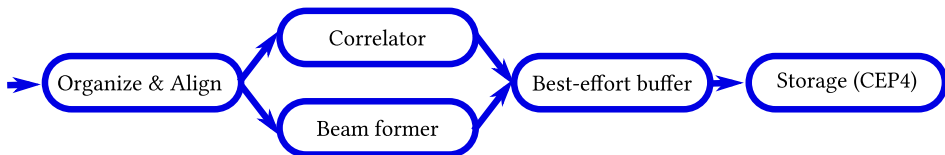


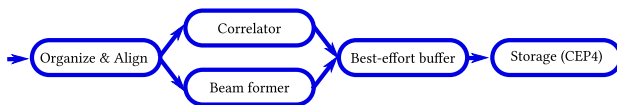


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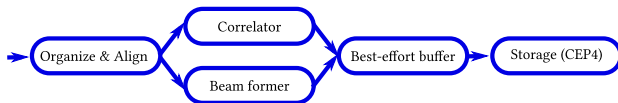
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- Sort incoming data by sample time
- Flag missing data
- Transpose data from “per station: all sub bands” to “per sub band: all stations”
- Coarse delay compensation: error $2.56 \mu\text{s}$
- Ship data to GPUs



Per station

- Polyphase filter
- Compensate remaining phase slope due to coarse delay step
- station sub band bandpass correction

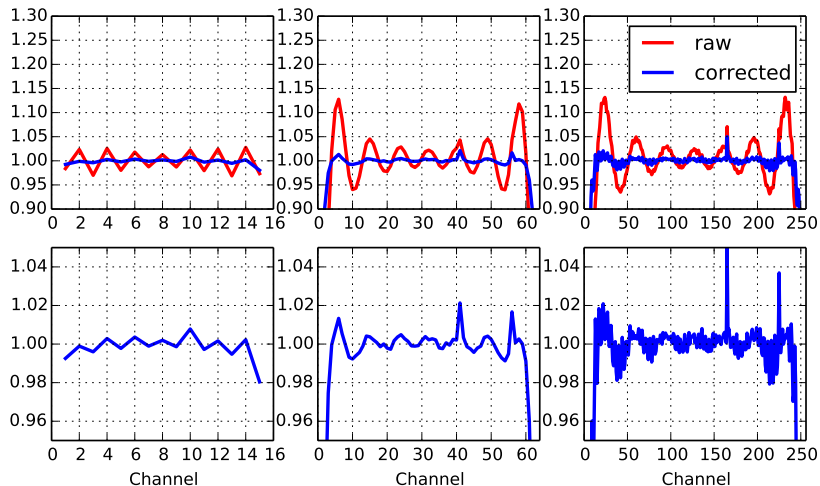
Per baseline per channel

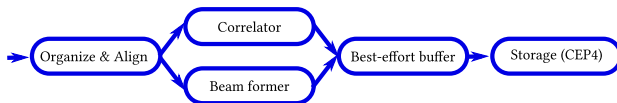
- Compute

$$\begin{pmatrix} x_i x_j^* & x_i y_j^* \\ y_i x_j^* & y_i y_j^* \end{pmatrix} \quad (1)$$

- Average to 0.25 – a few s

Beamformer station bandpass correction (CS)





Per station

- 256pt FFT
- phase slope correction
- sub band bandpass correction
- 256pt inverse FFT

Combine all fields

- Complex Voltage: $\sum_i \mathbf{e}_i$ OR
- Coherent Stokes: $\text{Stokes}(\sum_i \mathbf{e}_i)$ OR
- Incoherent Stokes: $\sum_i \text{Stokes}(\mathbf{e}_i)$
- Average to $5.12 \mu\text{s} - \sim 0.01 \text{ s}$ (Stokes modes)
- Can be done on dozens of “tied array” beams simultaneously
- Output data rates up to 100 Gbit/s!

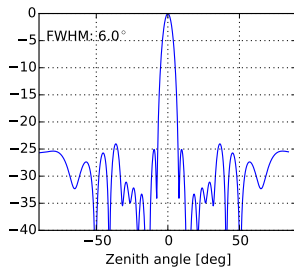
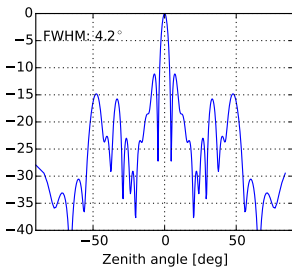
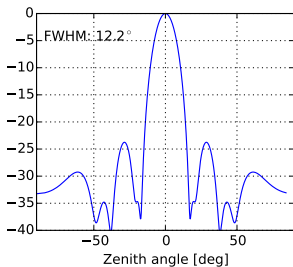
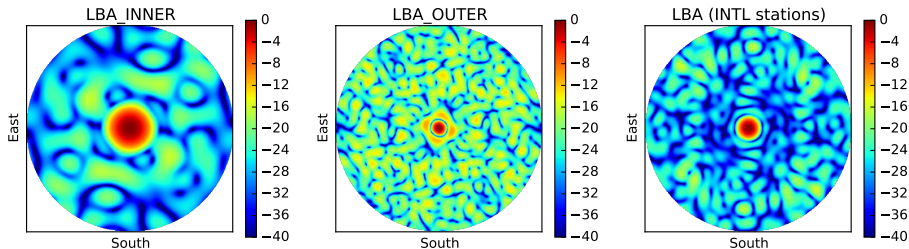
CEP4

- Data *REDUCTION* (tens of TB to a few TB)
- Batch processing only (Slurm)
- No user access
- Send data off to Long Term Archive (LTA)

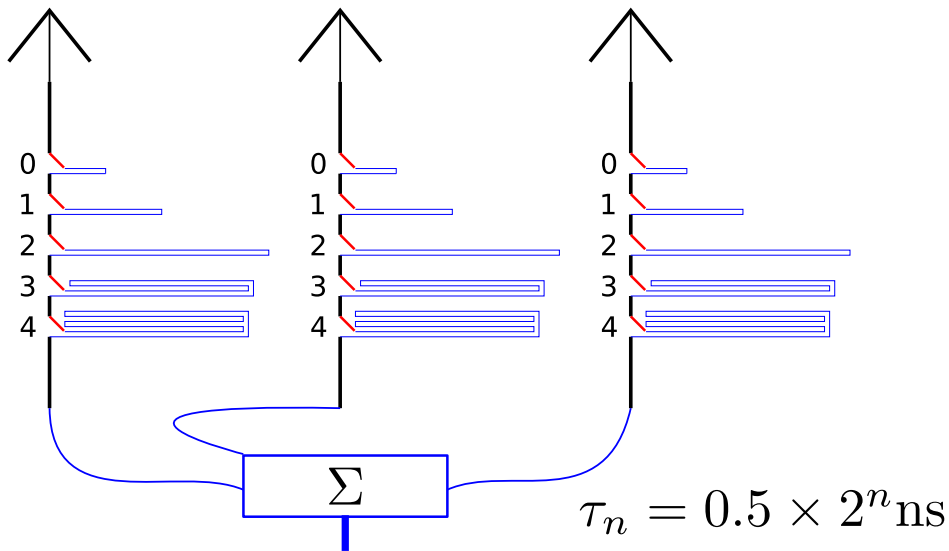
CEP3

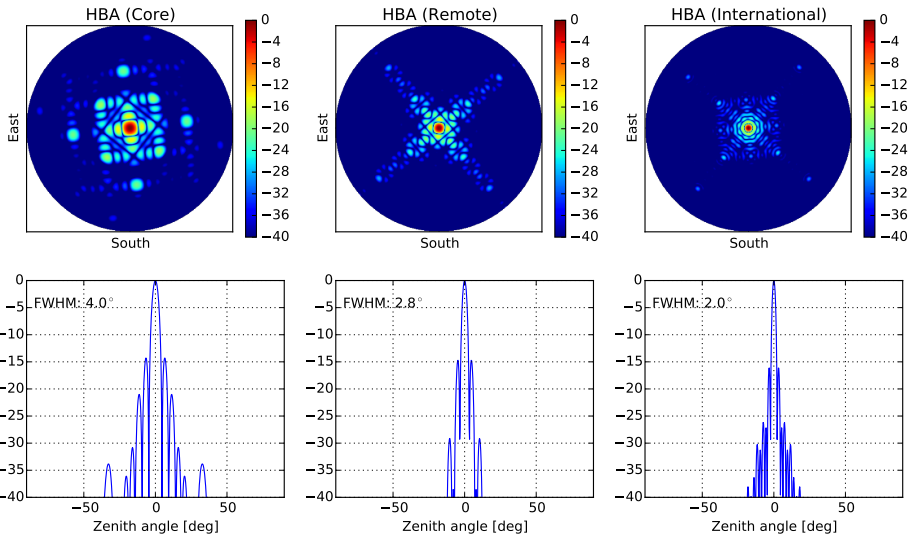
- user processing for limited time (\sim 4 weeks)
- all LOFAR software pre-installed
- 24 Dell PowerEdge R720 servers
- 128GB memory
- 20 Cores (2 ten-core Intel Xeon e5 2660v2 processors)
- Dell PERC H710P RAID controller 8 x 4TB disks in RAID6 setup, 22TB net disk space, XFS filesystem

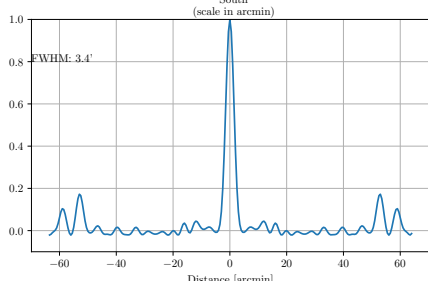
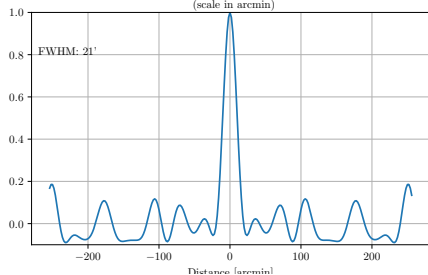
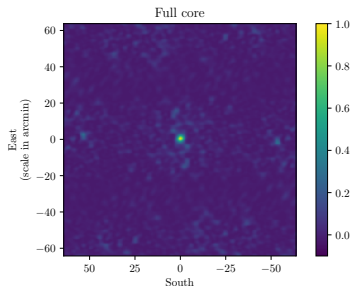
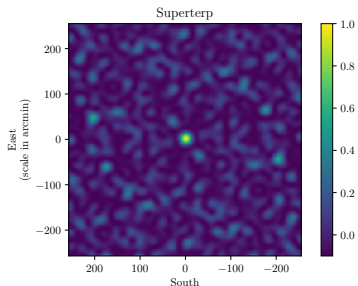
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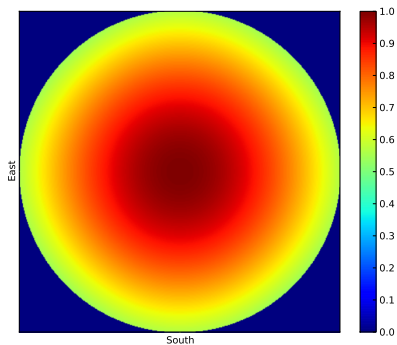
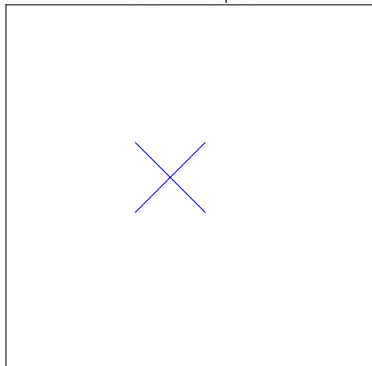


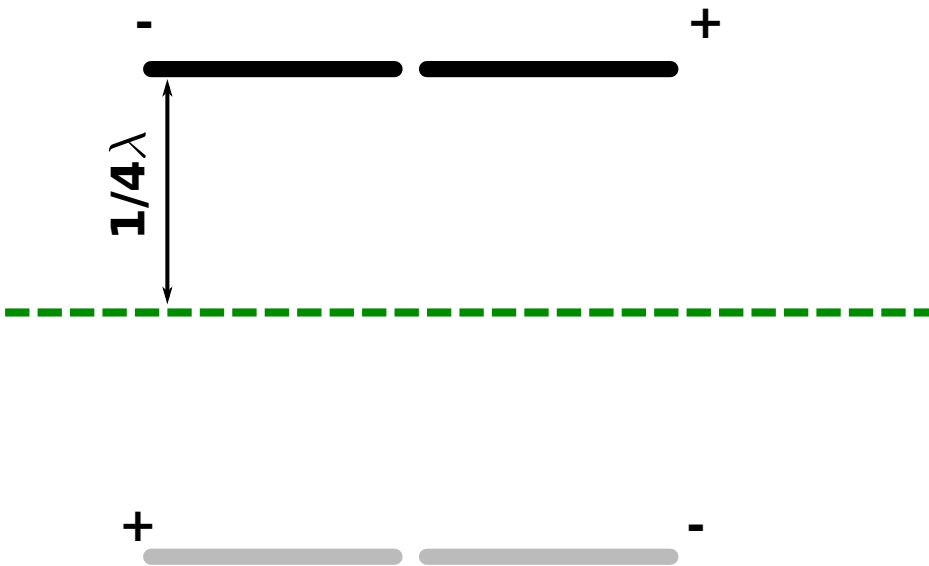




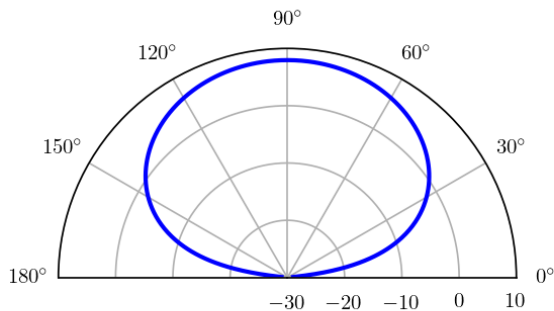
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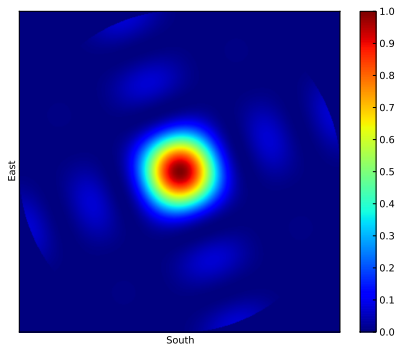
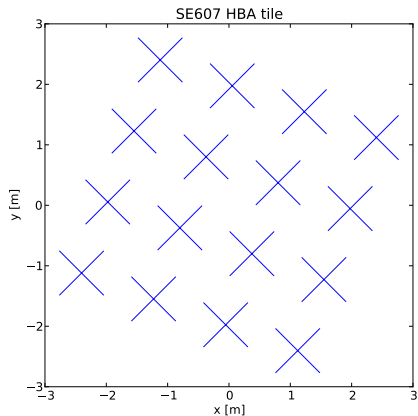
SE607 HBA dipole

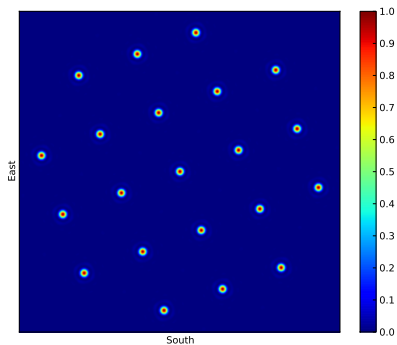
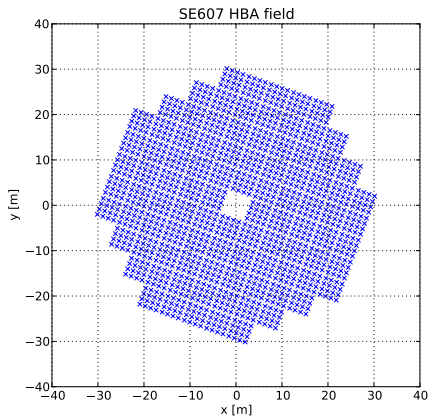


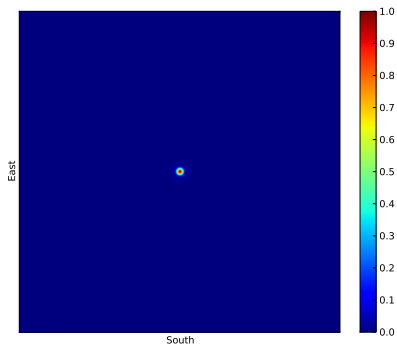
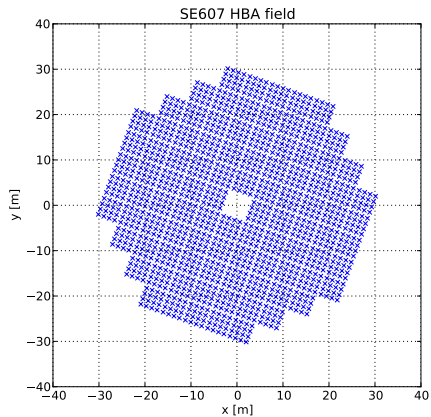


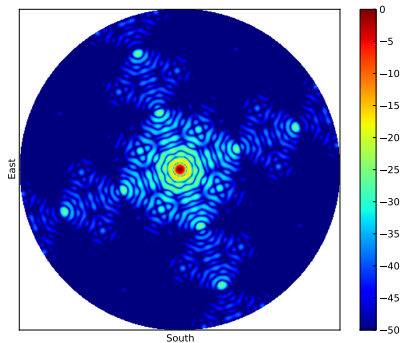
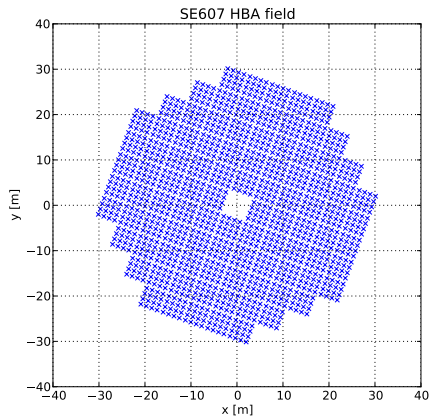
103 MHz

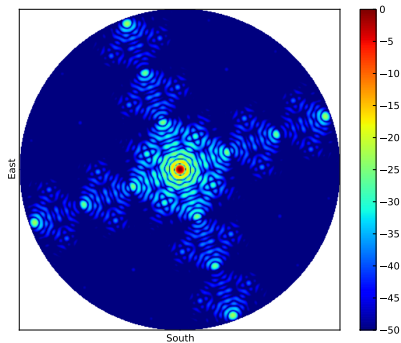
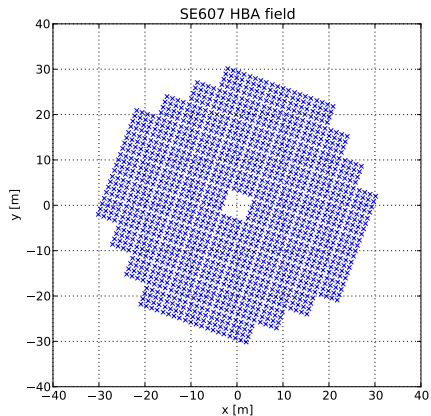




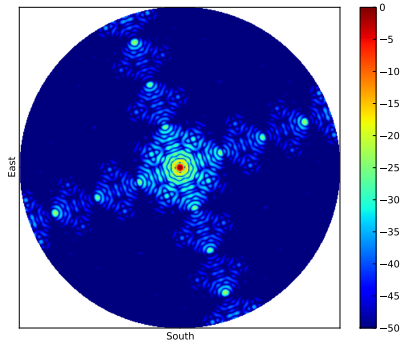
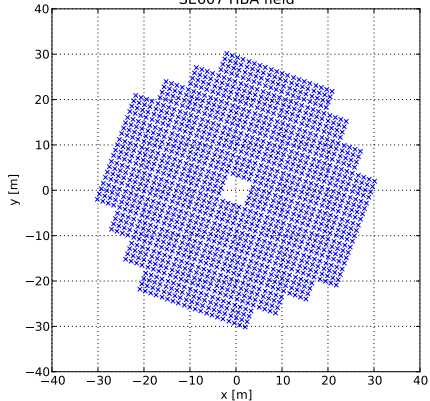


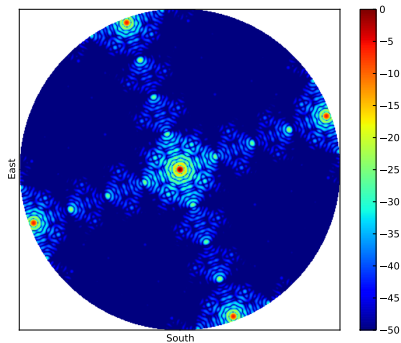
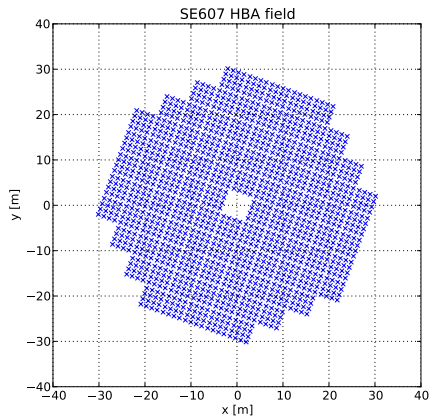


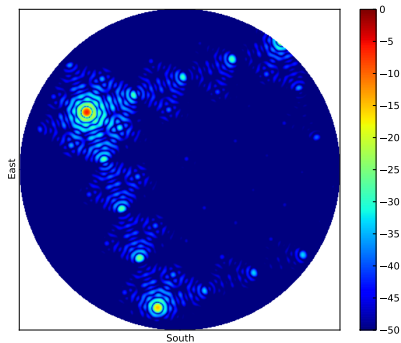
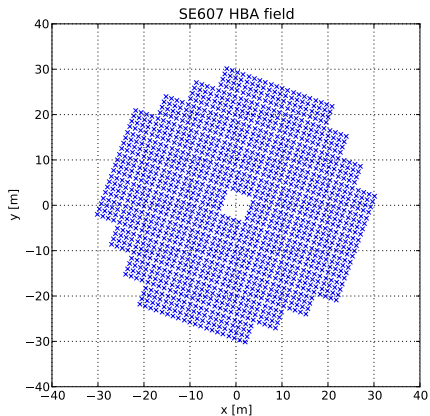


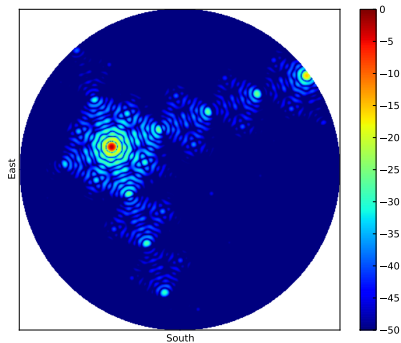
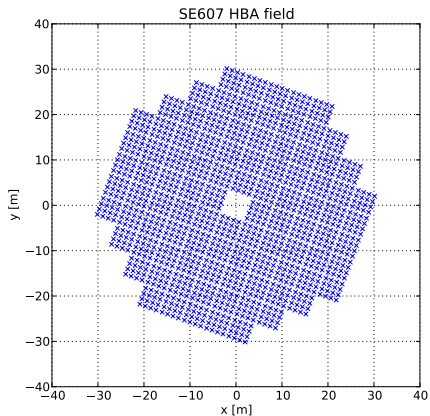


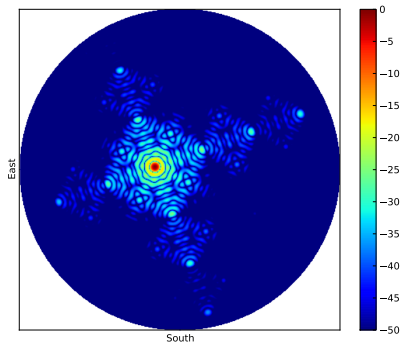
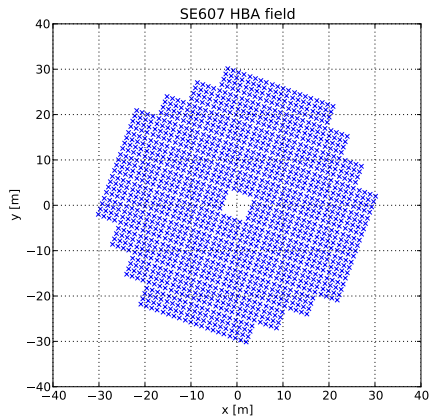
SE607 HBA field

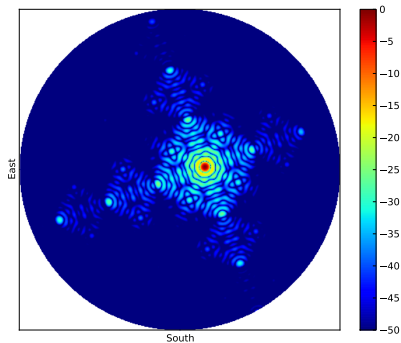
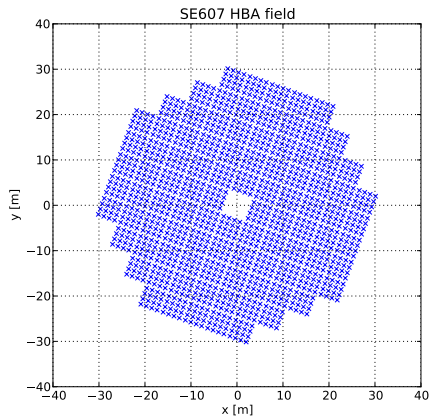


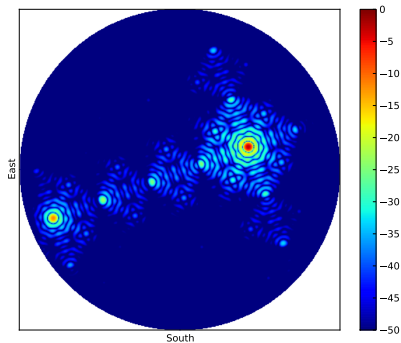
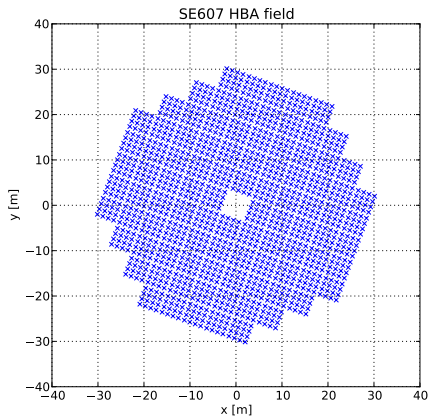


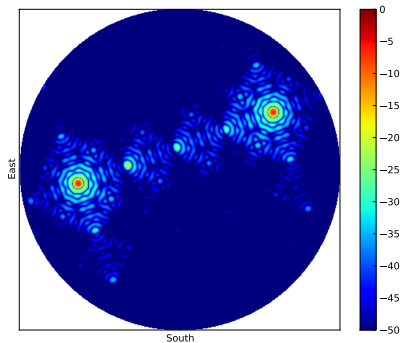
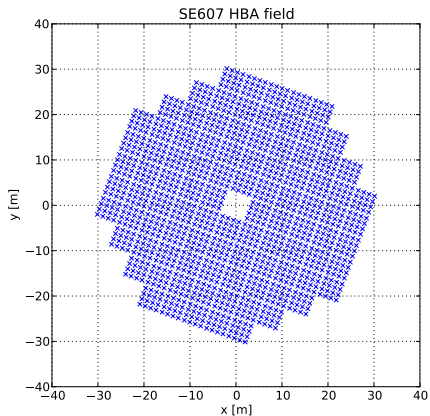


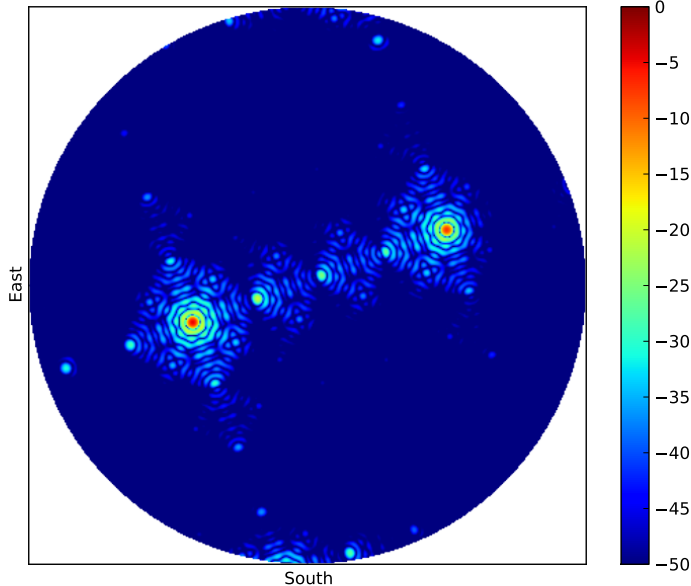


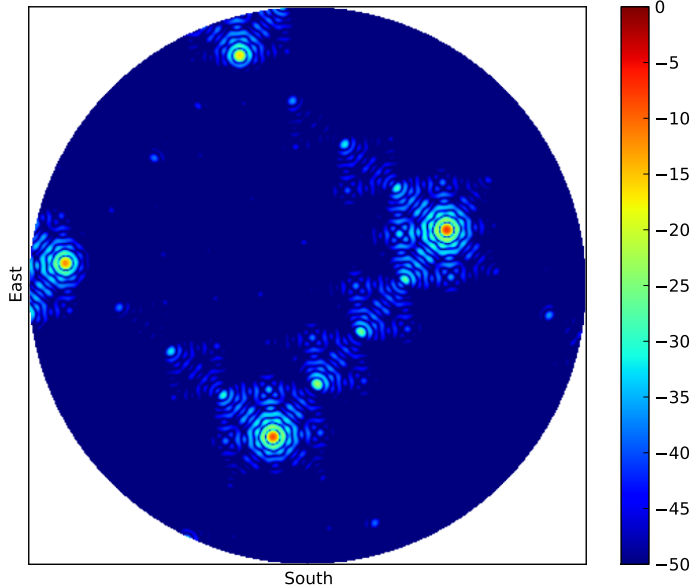


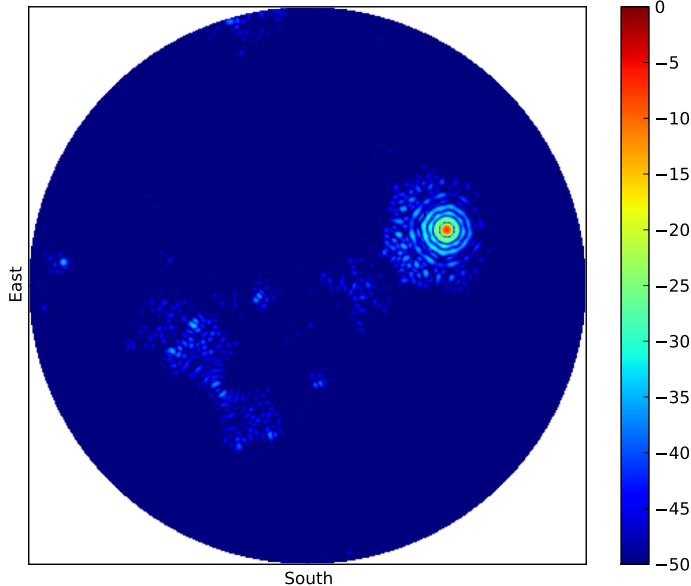












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