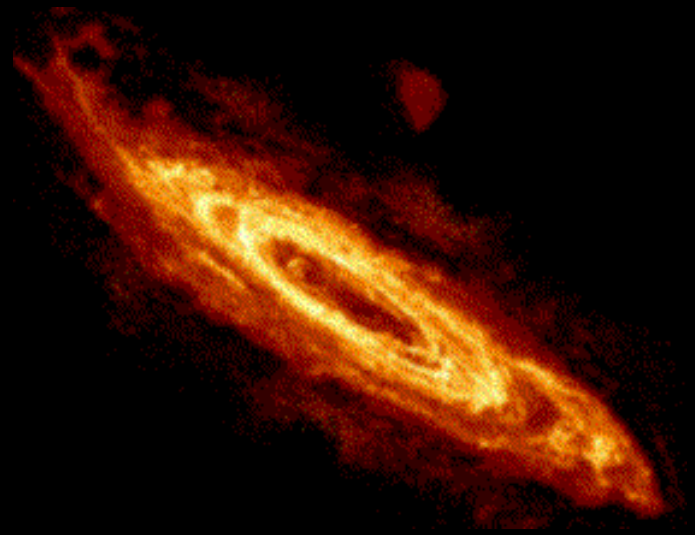
Digital Processing for LOFAR & Embrace

André W. Gunst

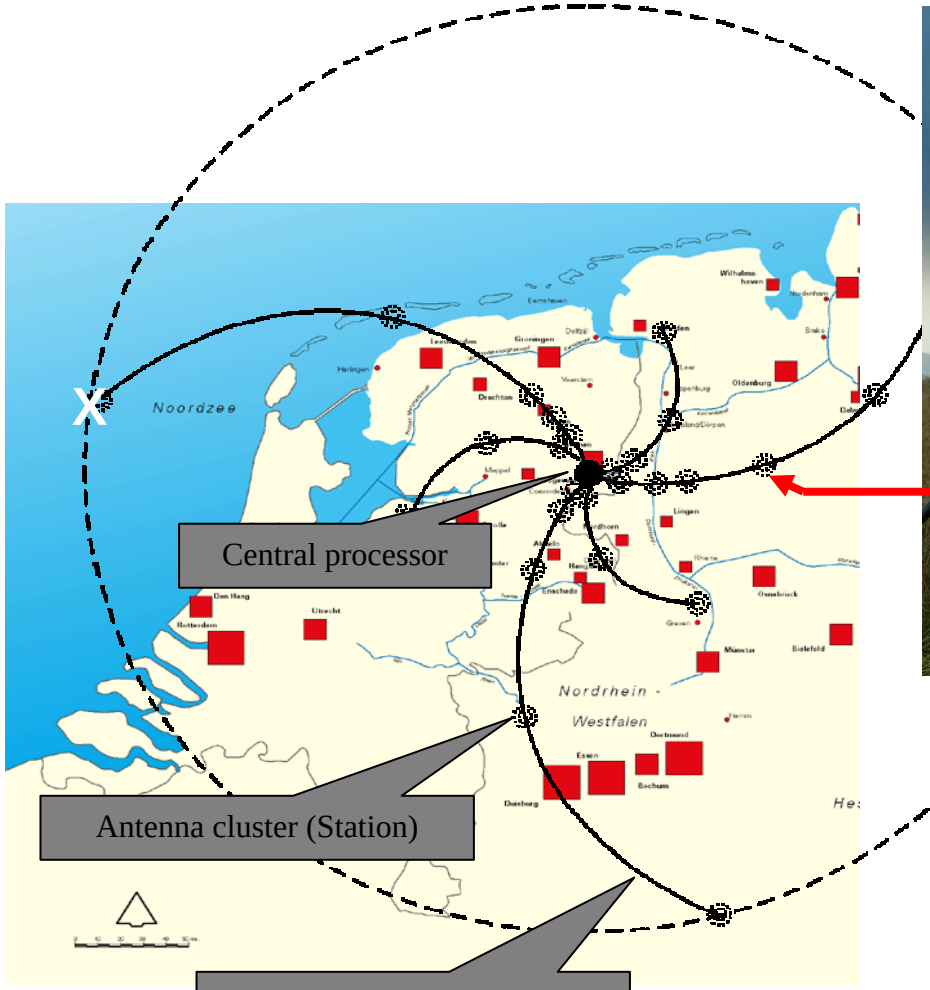


- Many small antenna elements
  - No mechanical parts necessary
  - Mass production
  - Electronic beam steering possible
  - Multi-beam capabilities

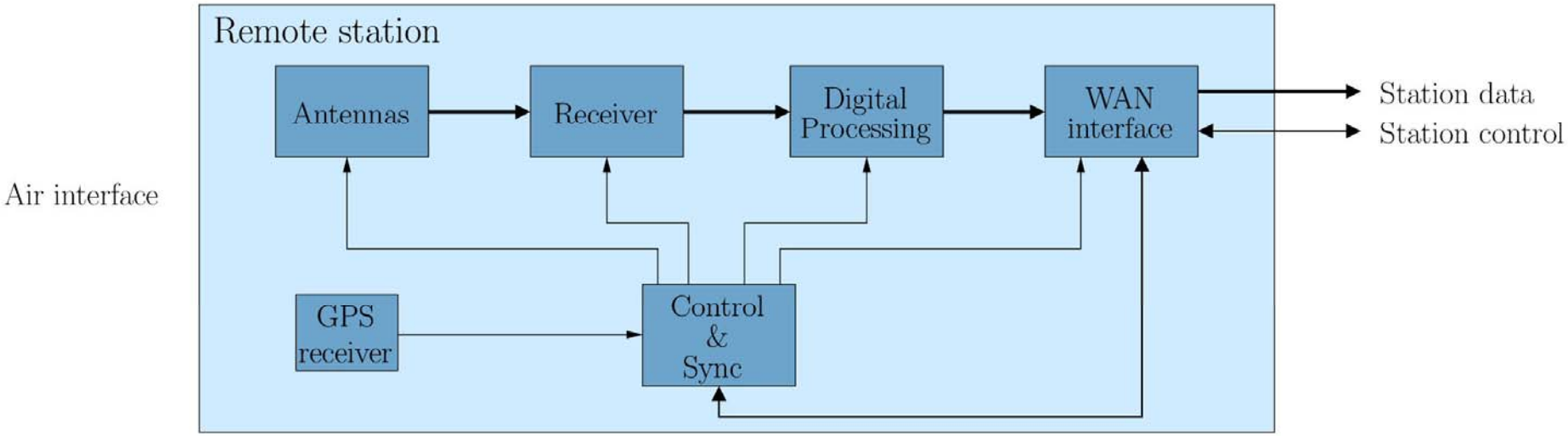
LOw Frequeny Array characteristics

- Phased array antennas
- Diameter of about 100 km
- Low frequency window
- Order 10^4 antennas
- RFI robust
- Large data network
- Central distributed super computer
- Flexible/reconfigurable

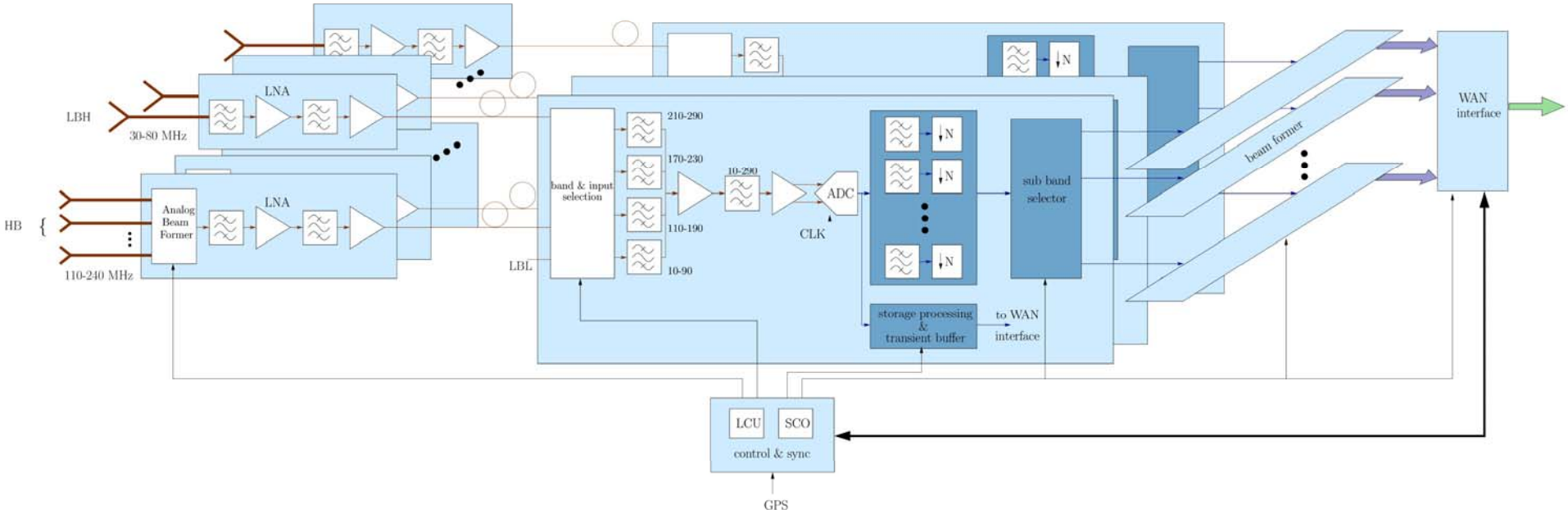
LOFAR Configuration



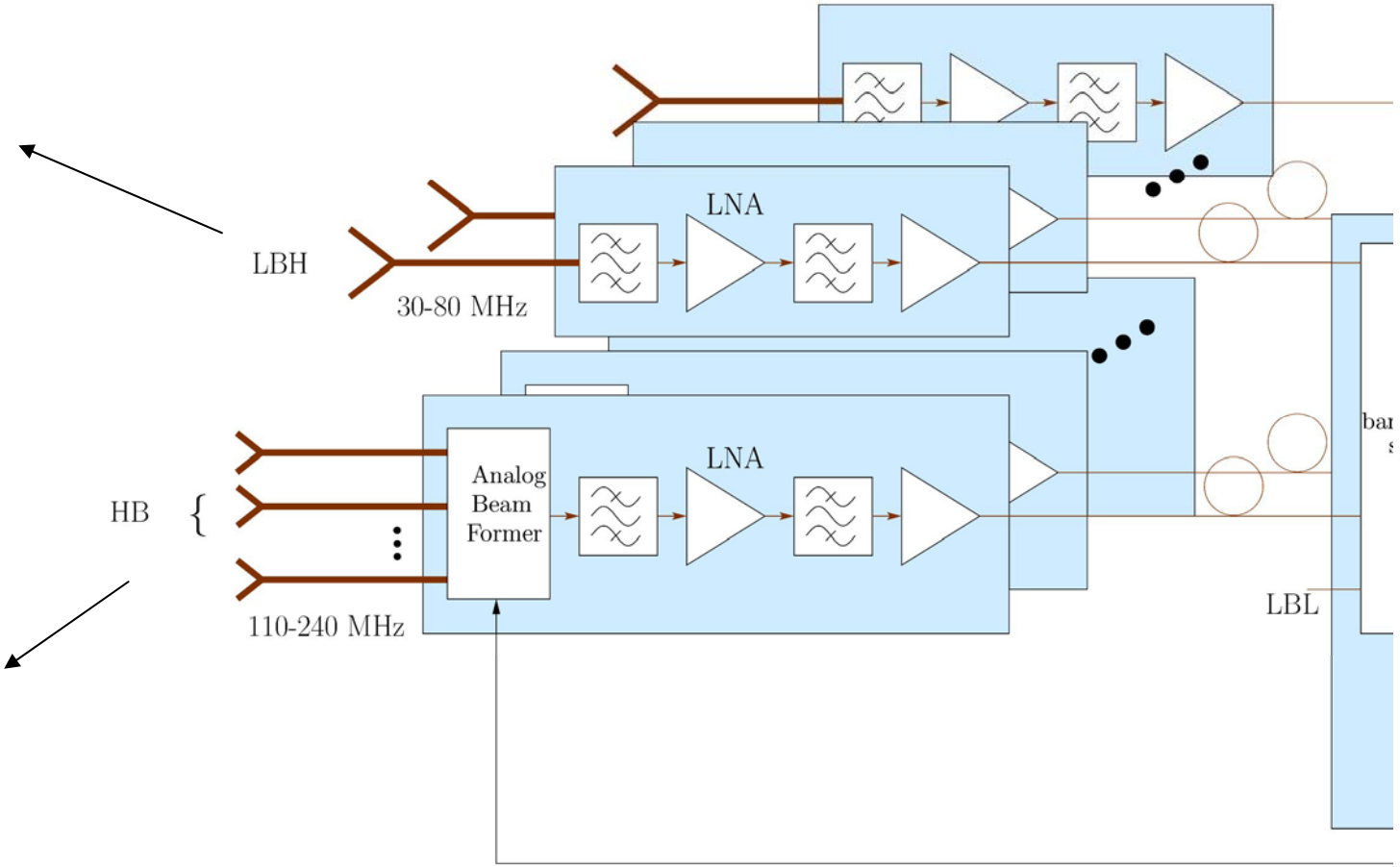
Remote Station Architecture



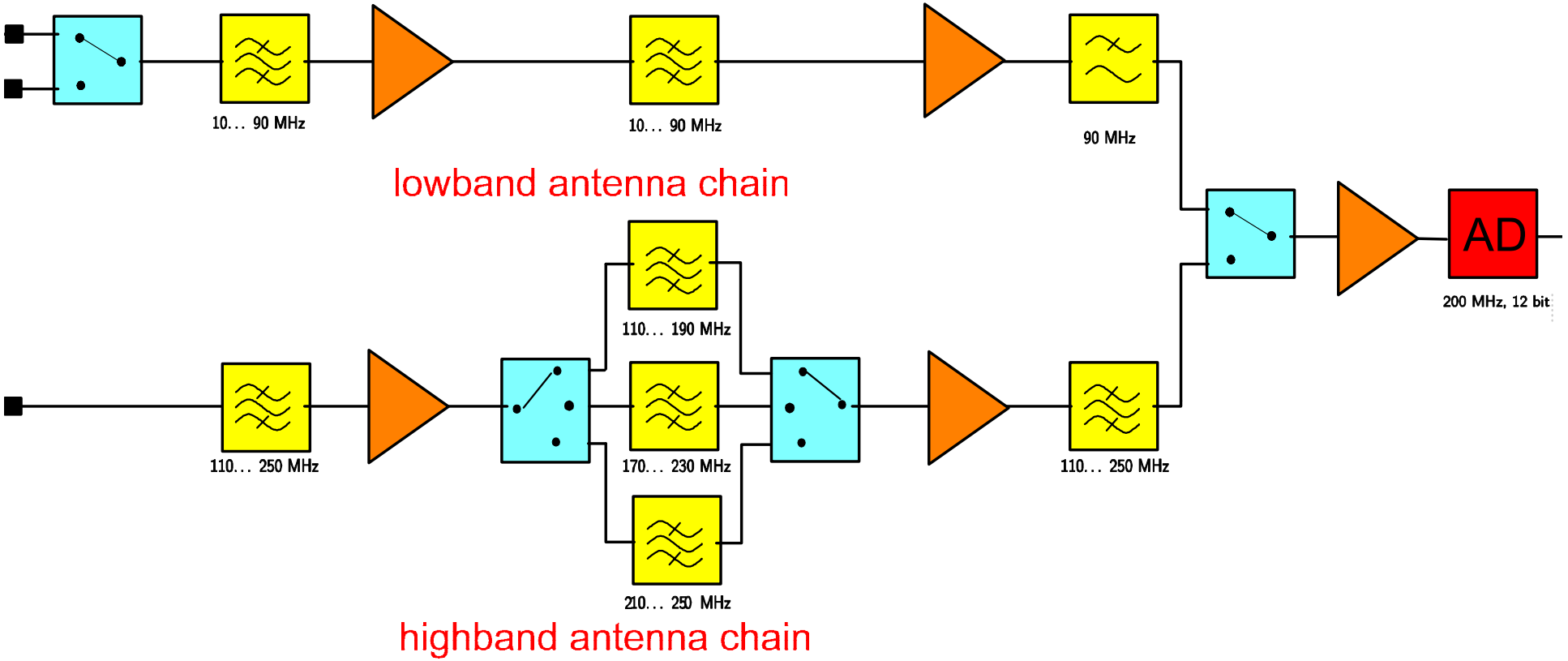
Remote Station Architecture (detailled)



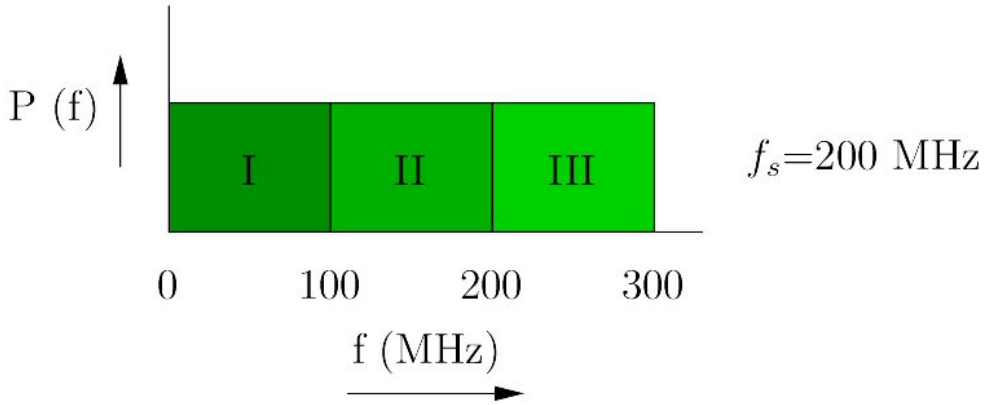
Antennas

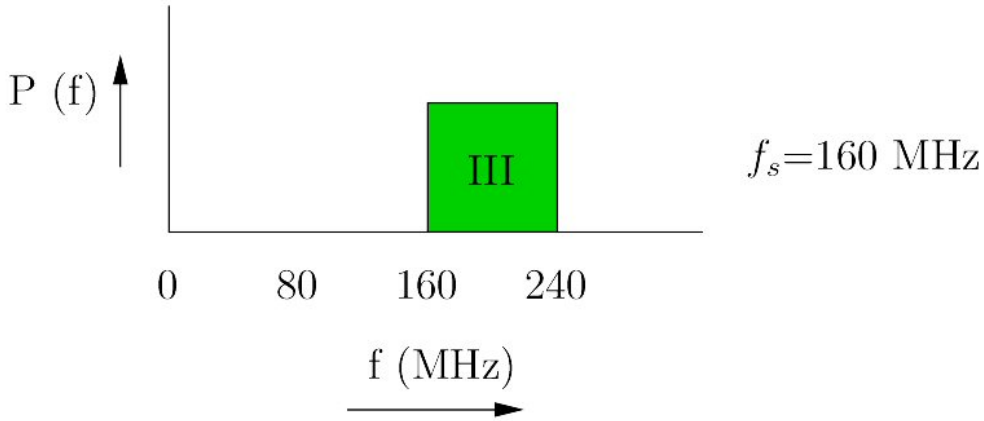


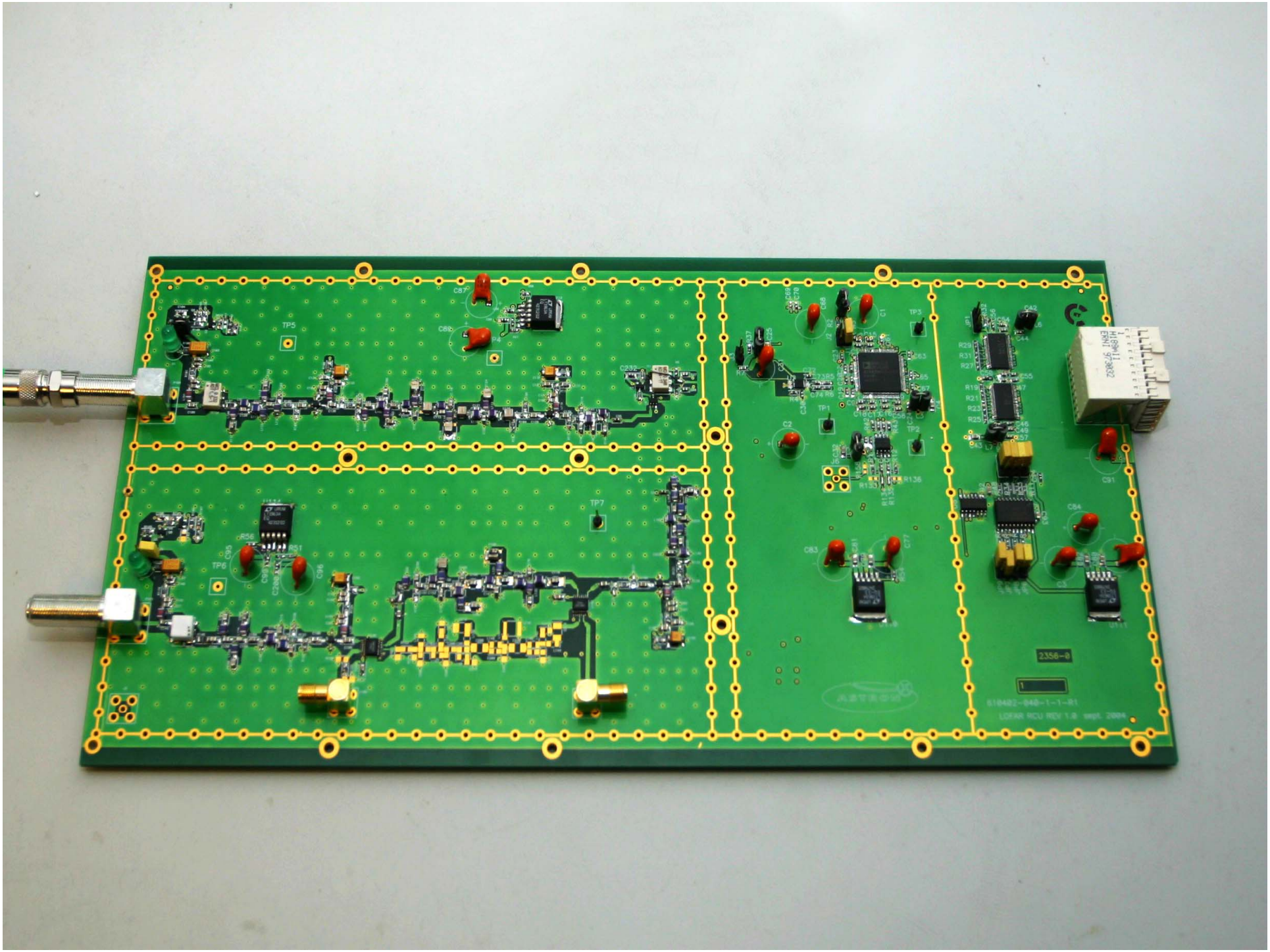
Receiver



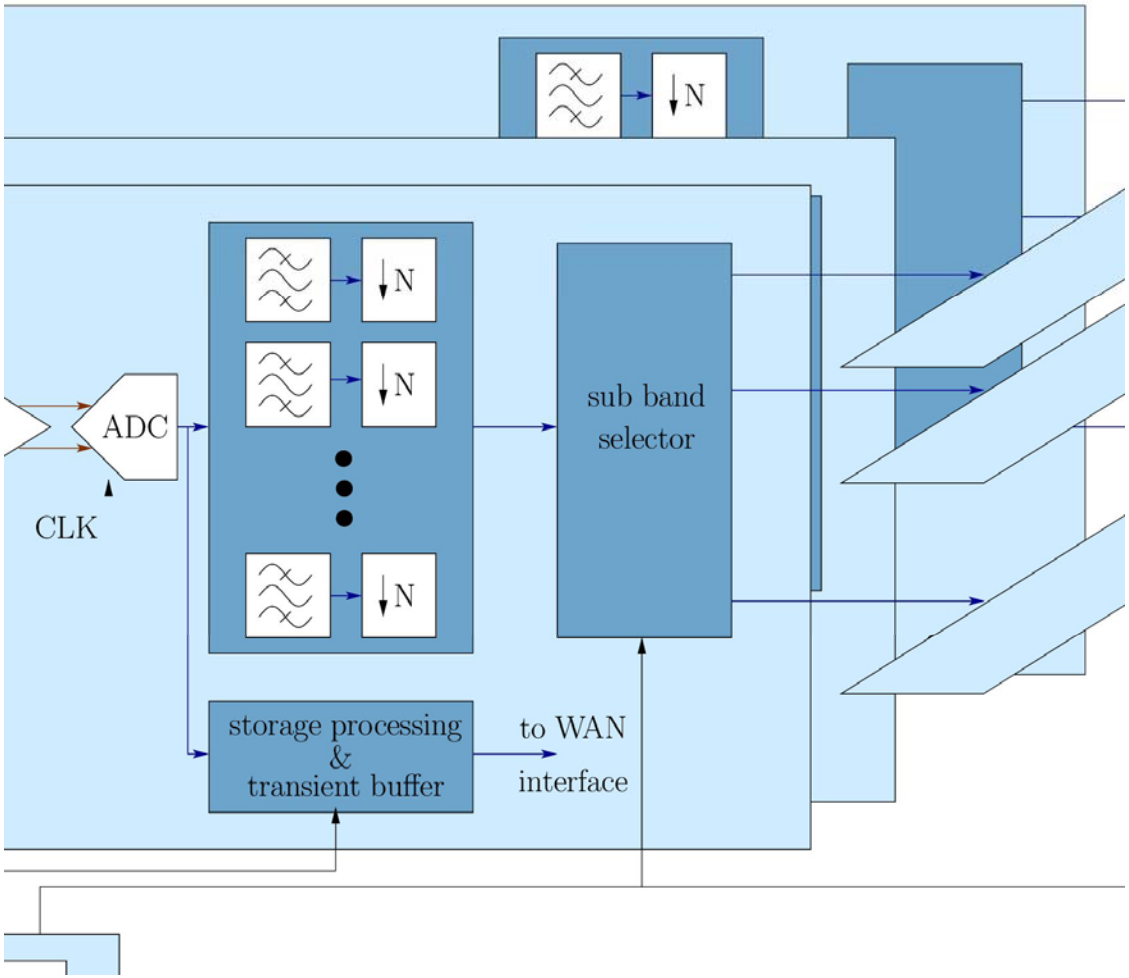
Direct Conversion Architecture

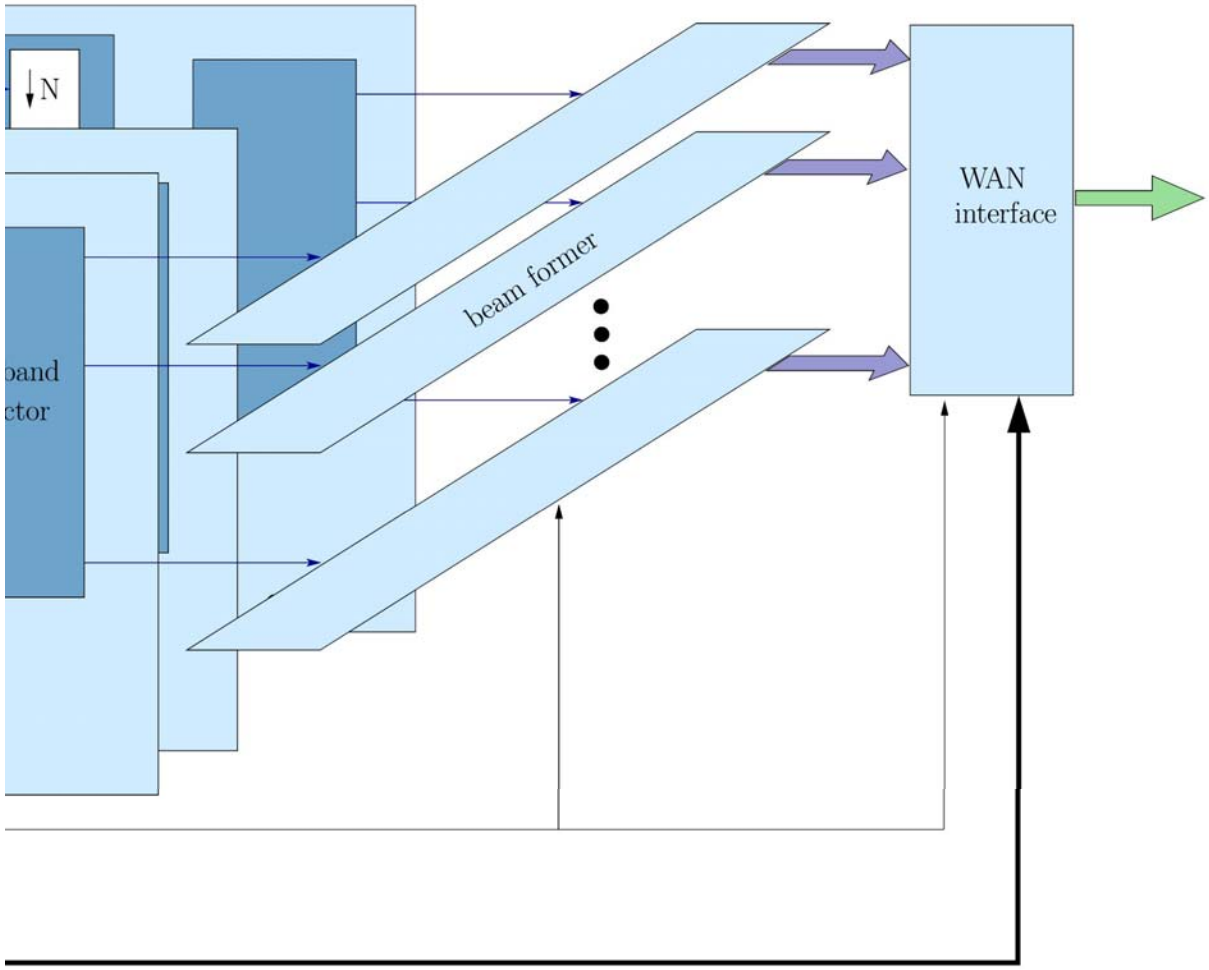


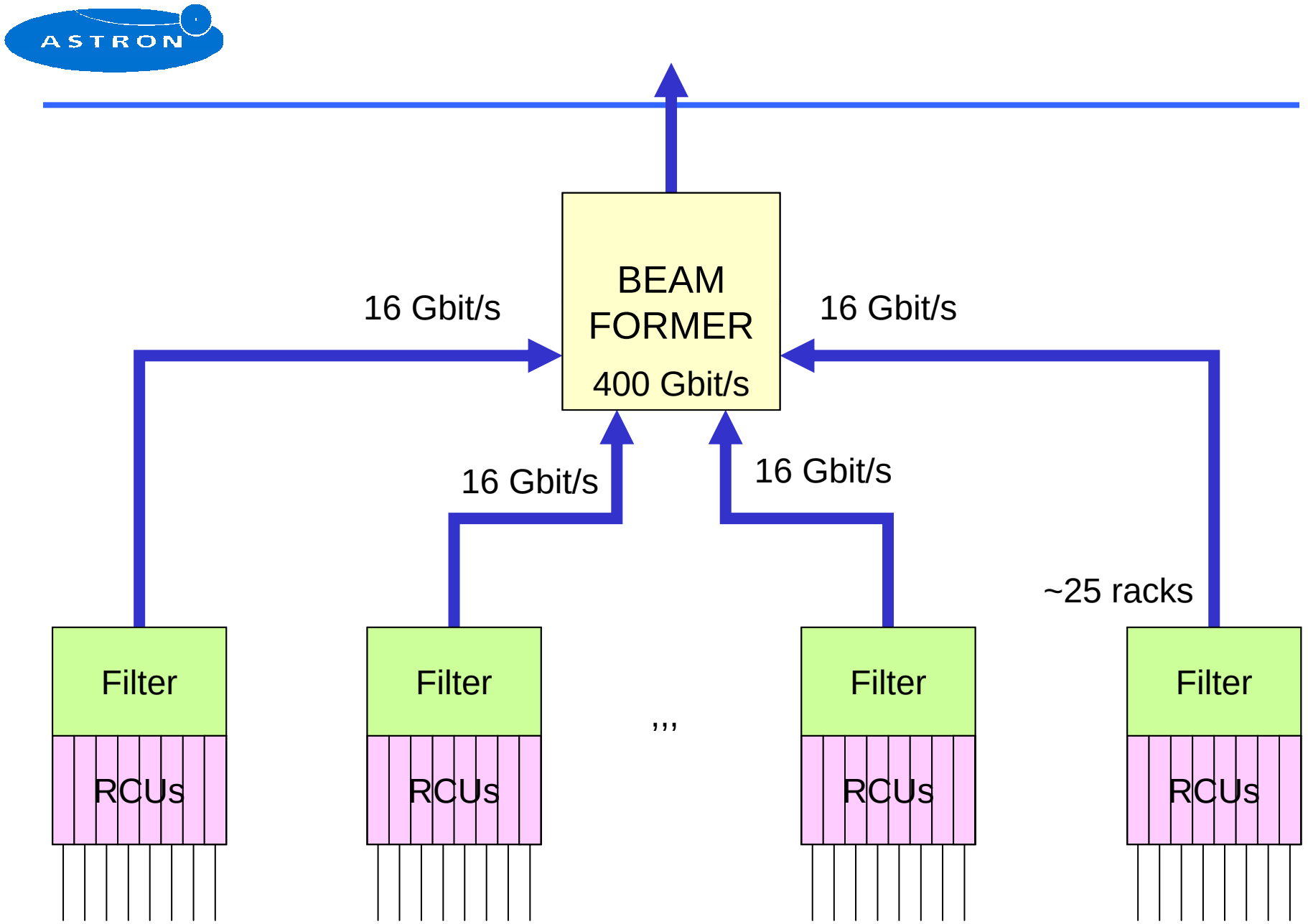


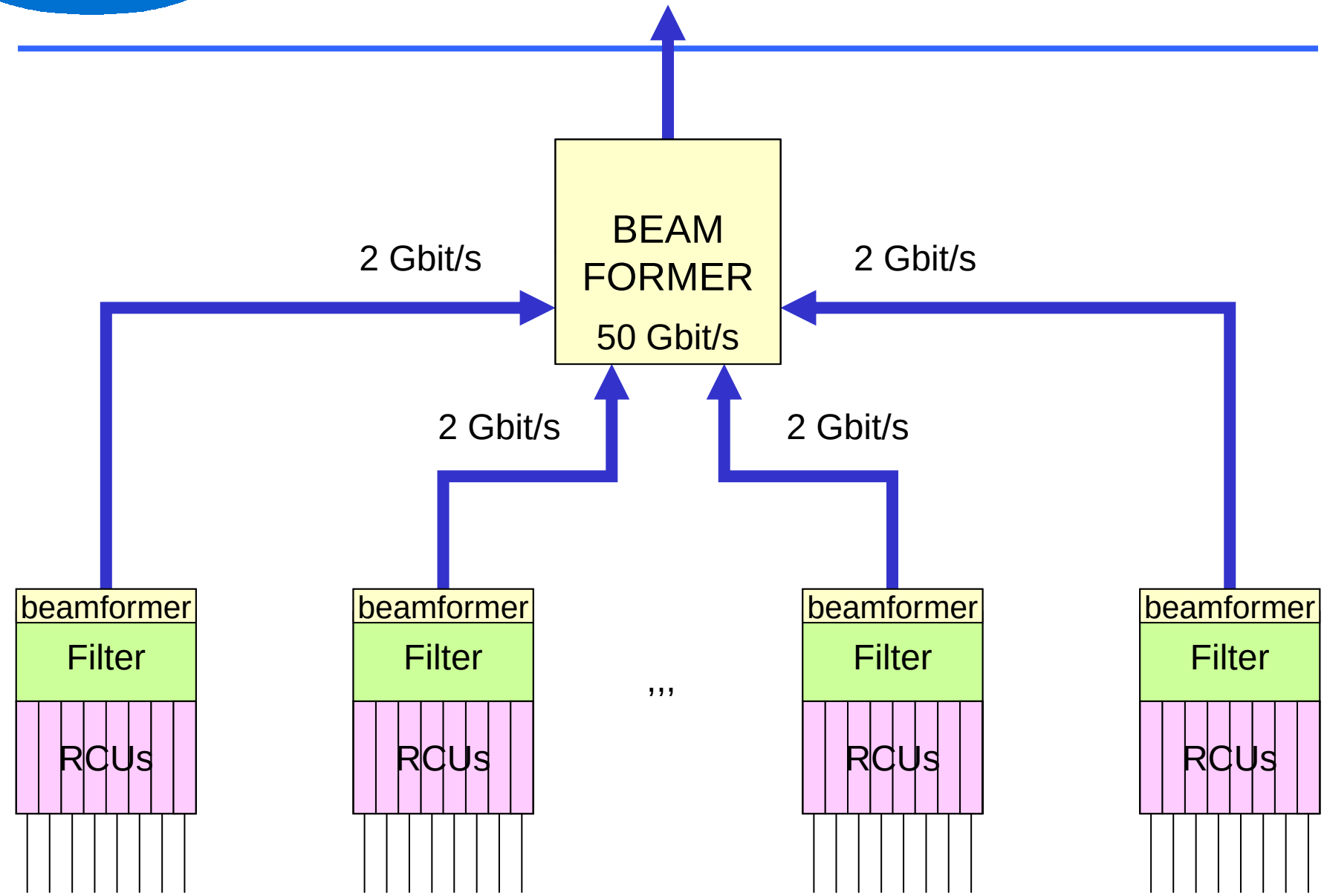

TP5
TP6
TP7
TP1
TP2
TP3
2358-B
LOFAR RCU REV 1.0 sept. 2004

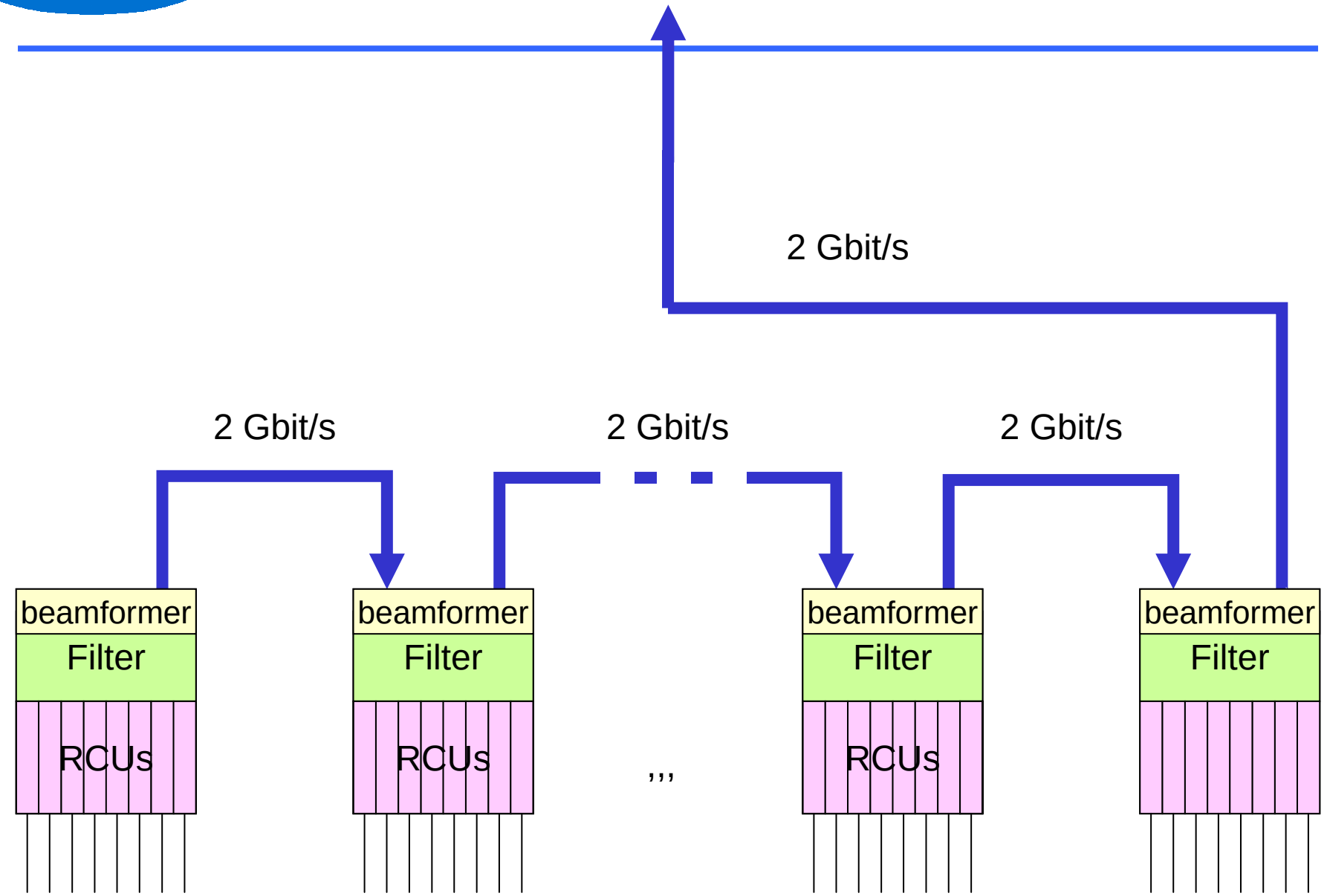
Digital Processing

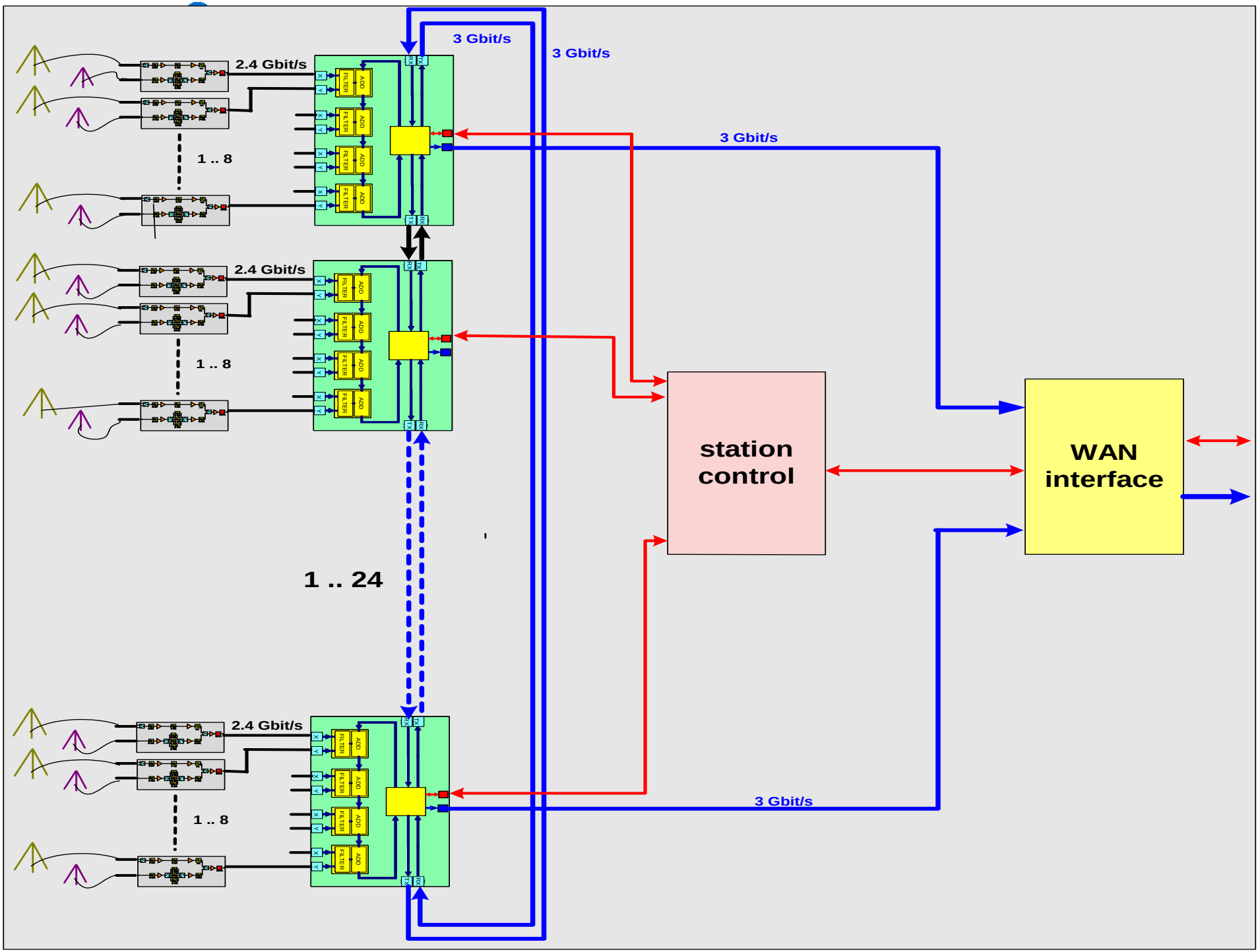





BEAM
FORMER
400 Gbit/s
16 Gbit/s
16 Gbit/s
16 Gbit/s
16 Gbit/s
~25 racks
Filter
RCUs
Filter
RCUs
,,,
Filter
RCUs
Filter
RCUs
~192 receiver units

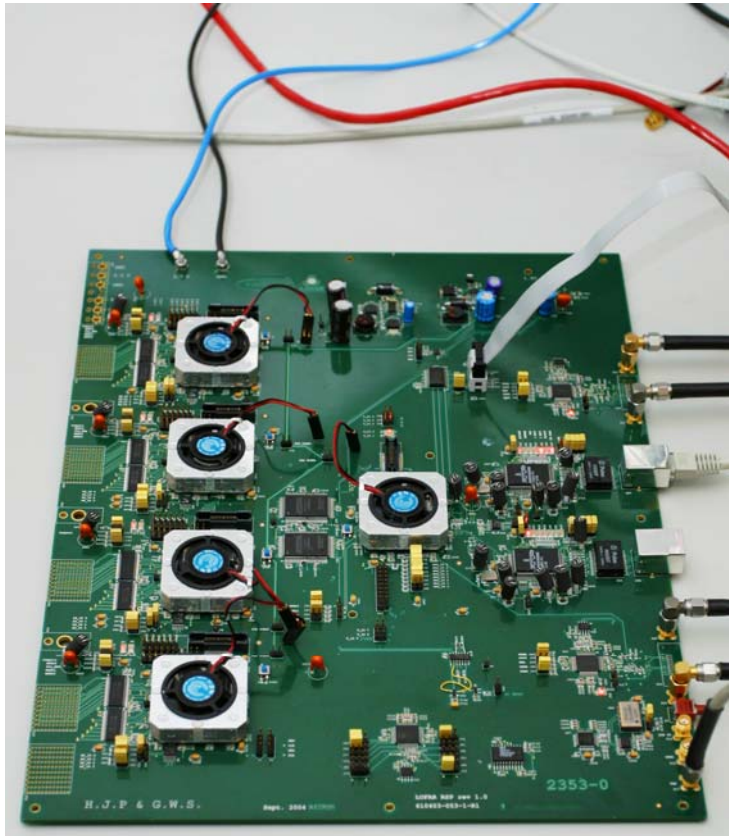

BEAM
FORMER
50 Gbit/s
2 Gbit/s
2 Gbit/s
2 Gbit/s
2 Gbit/s
beamformer
Filter
RCUs
beamformer
Filter
RCUs
,,,
beamformer
Filter
RCUs
beamformer
Filter
RCUs


2 Gbit/s
2 Gbit/s
2 Gbit/s
2 Gbit/s
beamformer
Filter
RCUs
beamformer
Filter
RCUs
,,,
beamformer
Filter
RCUs
beamformer
Filter


3 Gbit/s
3 Gbit/s
3 Gbit/s
2.4 Gbit/s
1 .. 8
2.4 Gbit/s
1 .. 8
1 .. 24
2.4 Gbit/s
1 .. 8
3 Gbit/s
station control
WAN interface
FILTER
ADD

- Splitting the 100 MHz band in 512 subbands
- Selecting subbands
- Digital beamforming with an update rate of 1 s
- Correlation at station level
- Storing data on a trigger

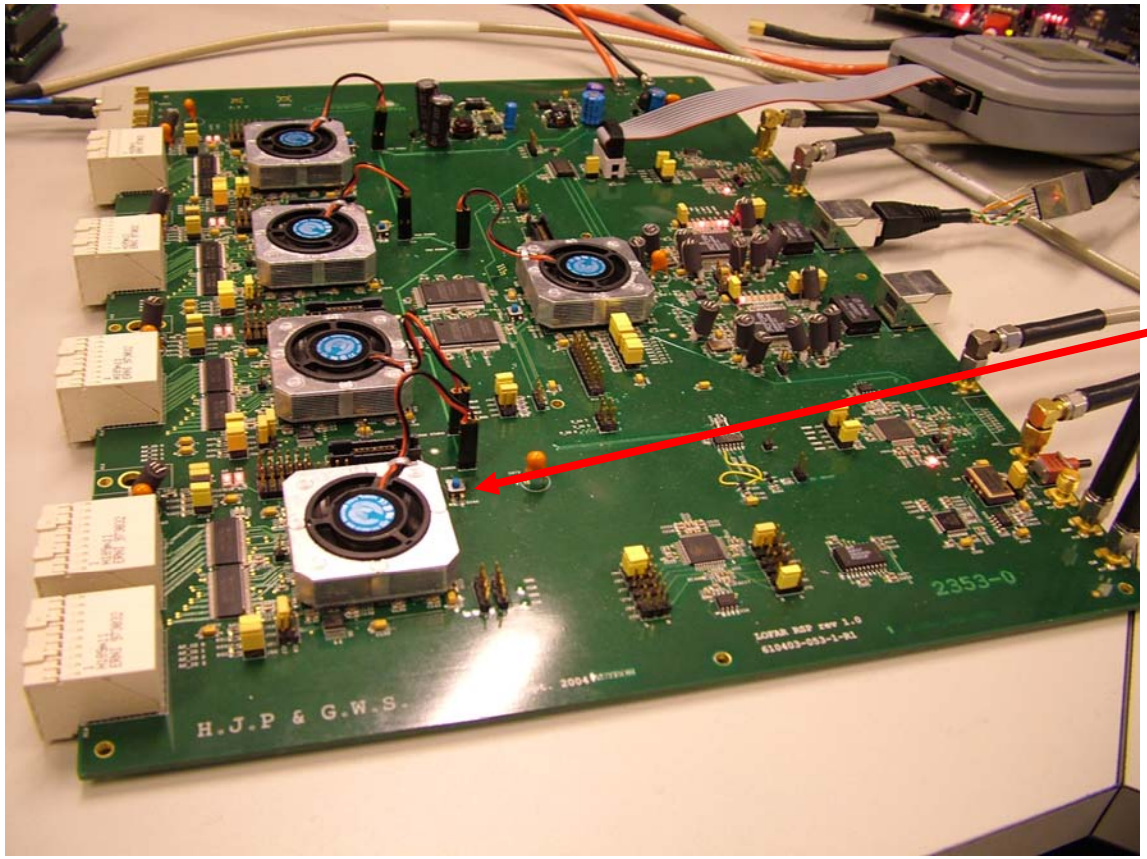
RSP-2 Board Characteristics



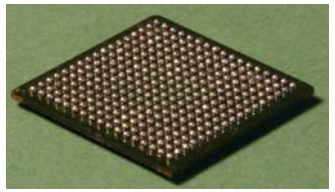
RSP-1

- Board size: 280x366.6 mm
- # layers: 12
- # connections: 6369
- # differential pairs: 439
- input bandwidth: 19.2 Gbps
- max. output bandwidth: 10 Gbps

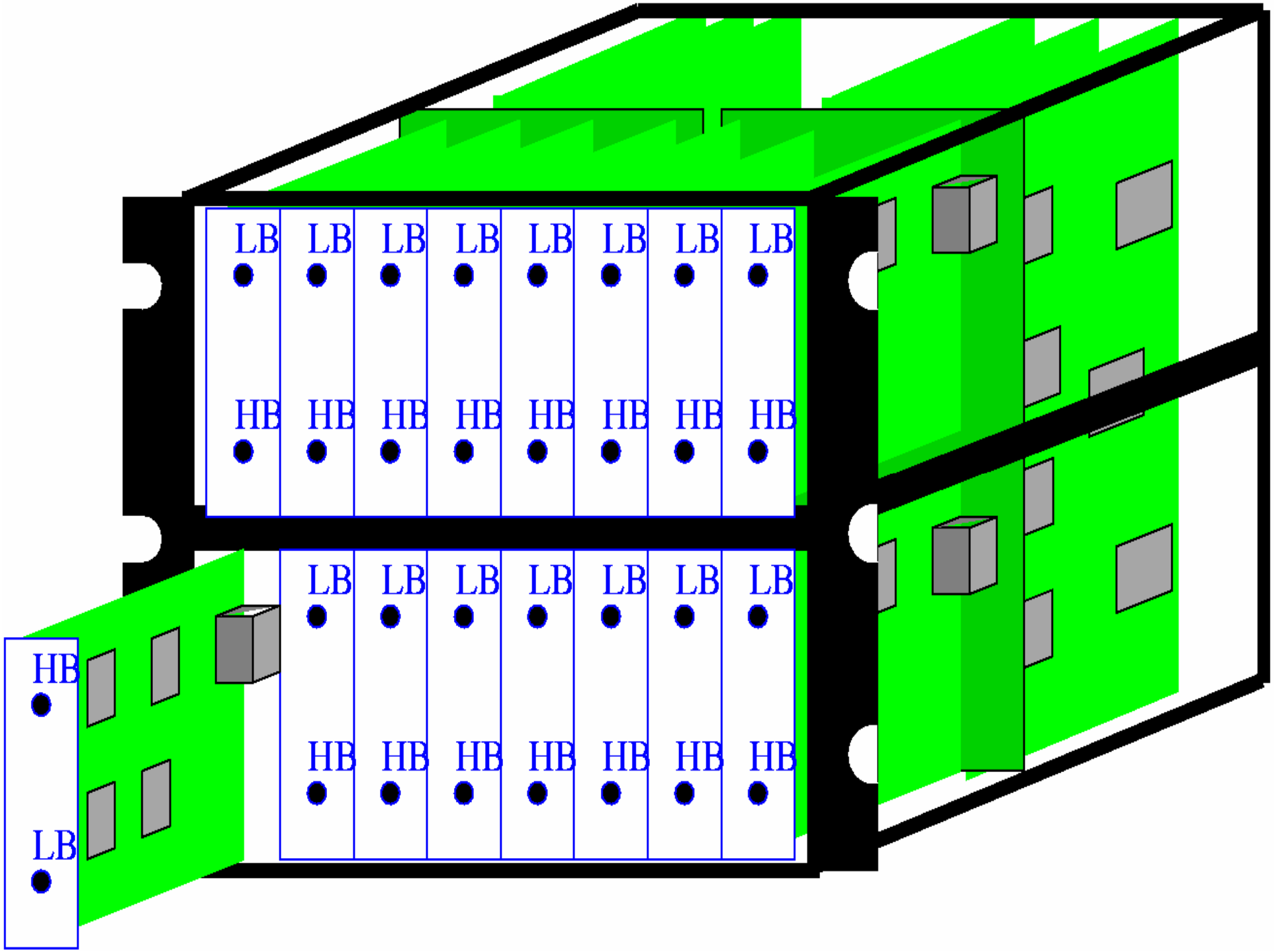
RSP-2 Chip Characteristics



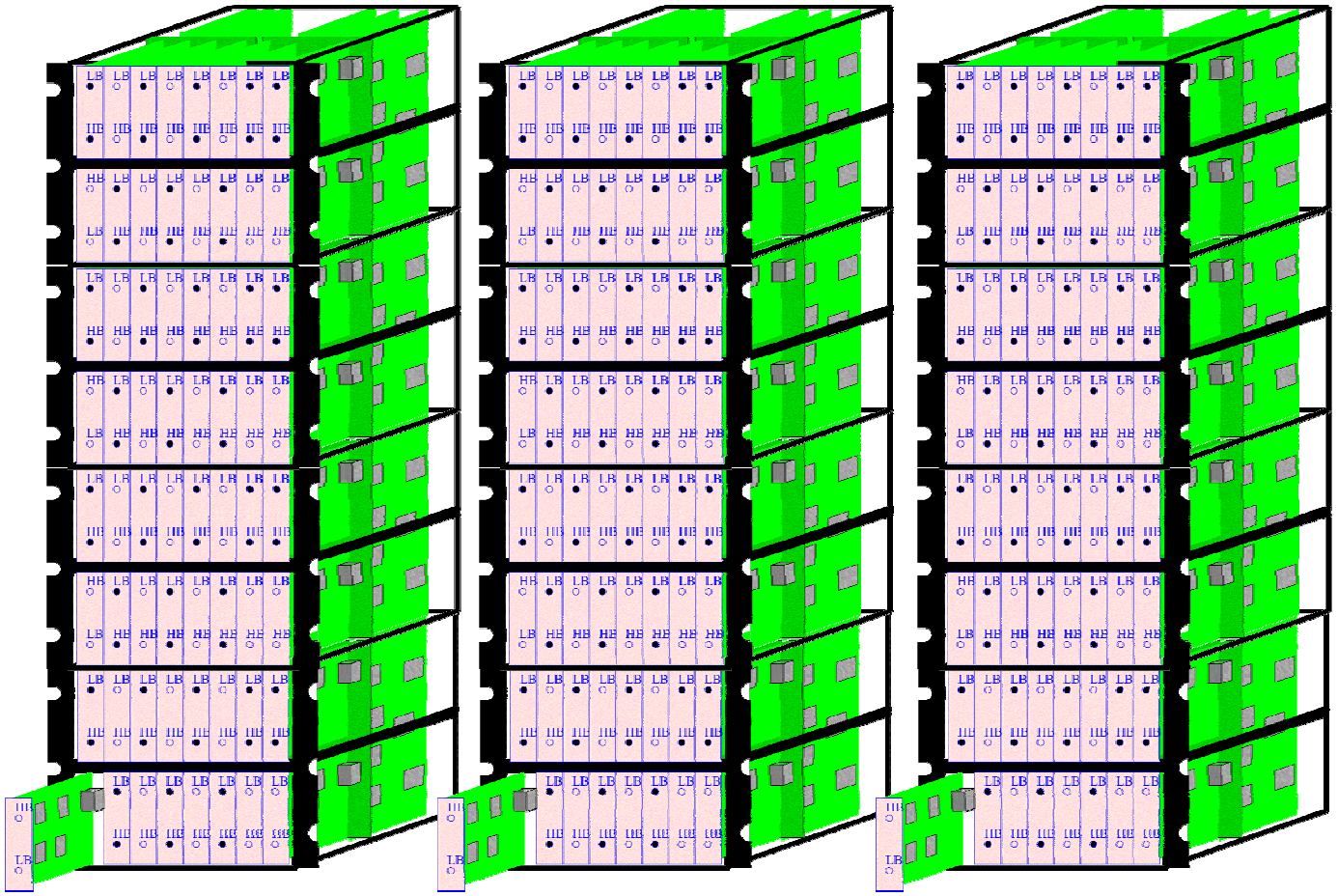
- 90 nm technology
- 192, 18x18 multipliers
- 4.5 Mbit RAM
- 1020 “balls” on chip



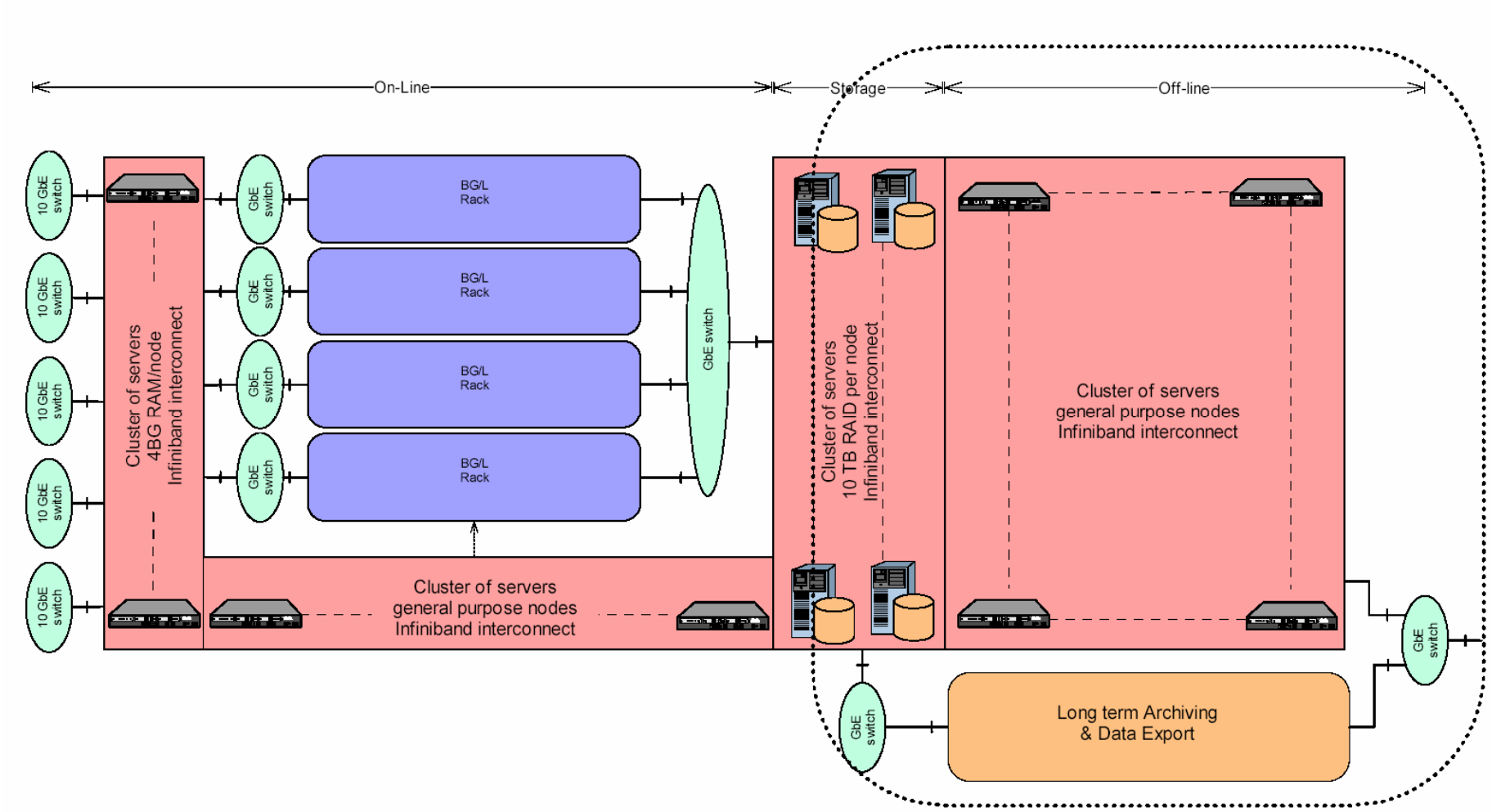
- Input data rate: ~ 460 Gbps
- Output data rate: ~ 2 Gbps
- Processing capacity: ~ 1.5 Tmul/s
- Storage capacity: 96 Gbyte


LB LB LB LB LB LB LB LB
HB HB HB HB HB HB HB HB
LB LB LB LB LB LB LB
HB HB HB HB HB HB HB
HB
LB

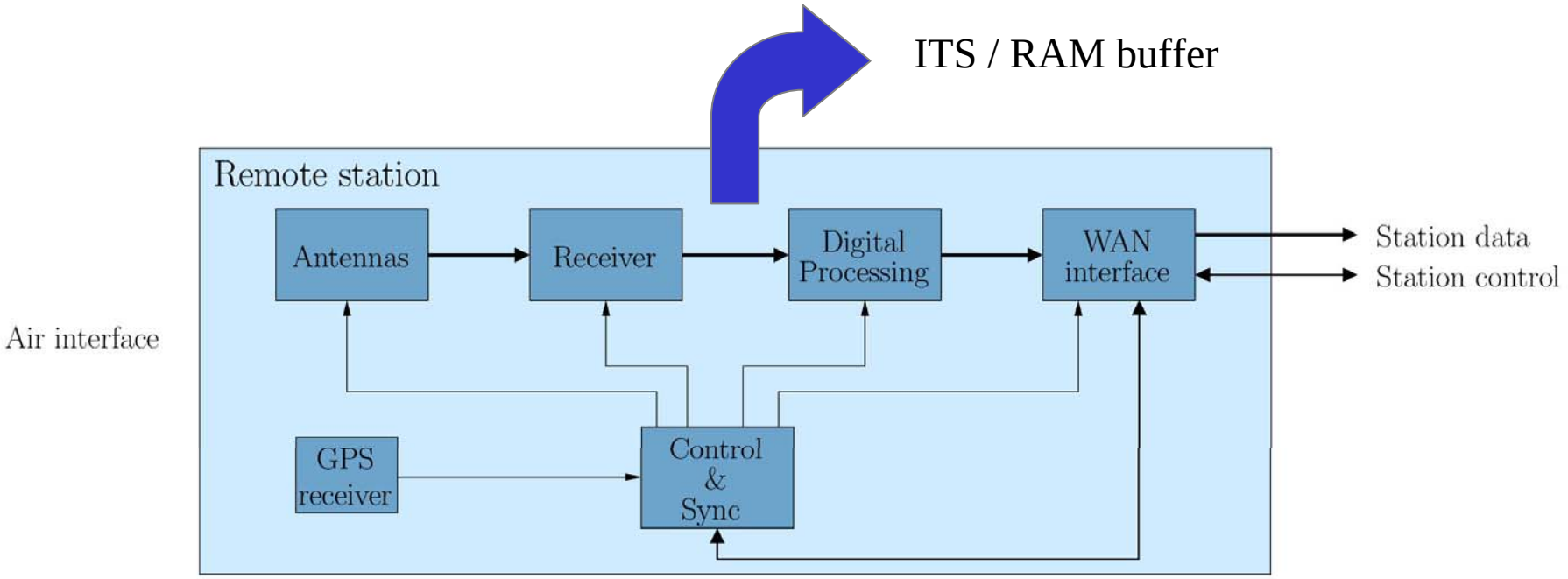
LOFAR Remote Station FTS-1 Hardware



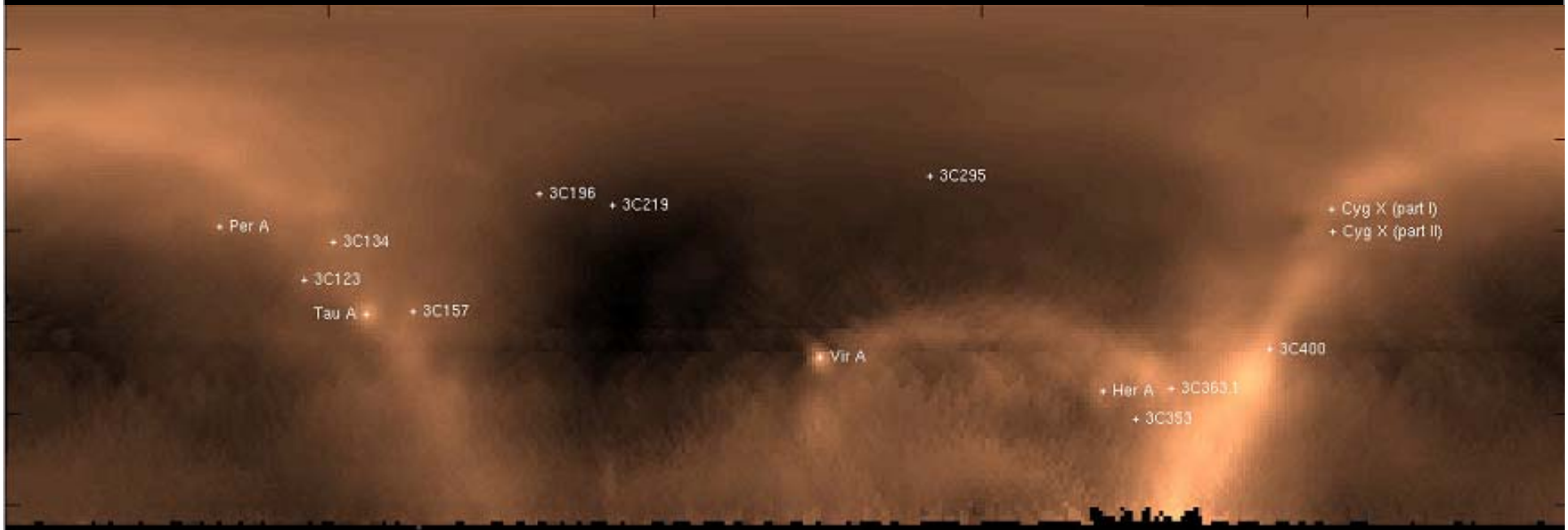
LOFAR Central Processor



Status end of 2003 (ITS)



Survey of the full sky made with a LOFAR Test Station



source	flux @178MHz (Jy)	source	flux @178MHz (Jy)
Perseus A	58	Hercules A	325
3C123	175	3C363.1	90
3C134	66	Cygnus X (part I)	230
Taurus A	1420	Cygnus X (part II)	410
3C157	210	3C353	203
3C196	59	3C295	73
3C219	44	3C400	400
Virgo A	970		

This map was produced using 86 snapshots with 6.7s of integration and 9.7kHz channels. First RFI free channels between 29.5 and 30.5 MHz were selected using a median filter. The selected channels were calibrated on the four strongest 3C sources (Cas A, Cyg A, Tau A, Vir A). After the calibration a first map was made by a flux conserving projection from the (l, m) grid of the individual snapshots to the (α, δ) grid of the all sky image. This map was dominated by the averaged out sidelobes of Cas A and Cyg A. Therefore these two sources were cleaned from the image resulting in this map.

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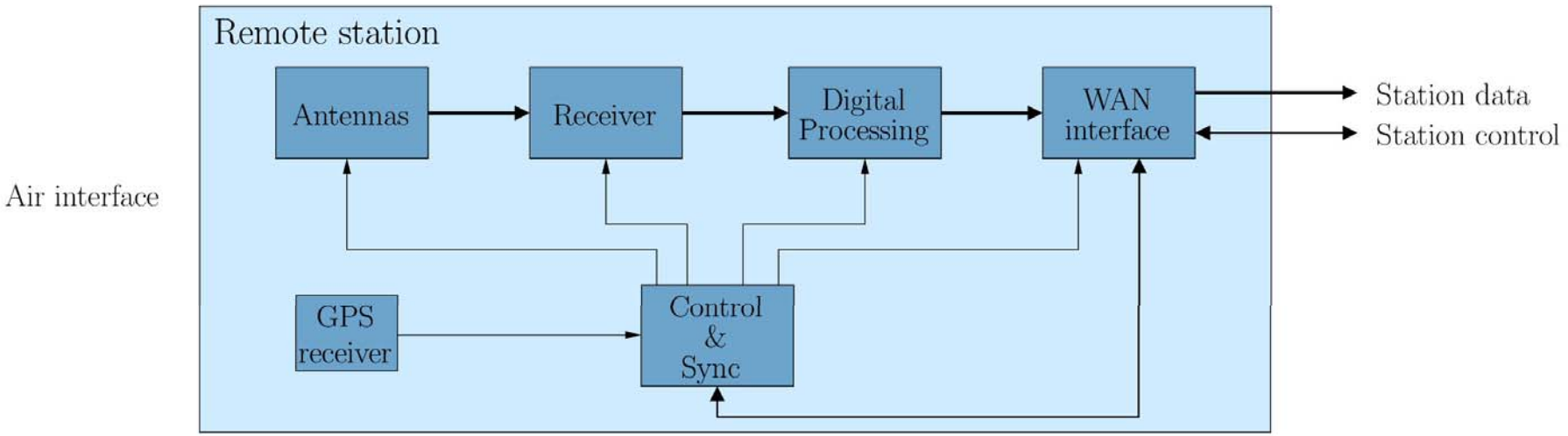
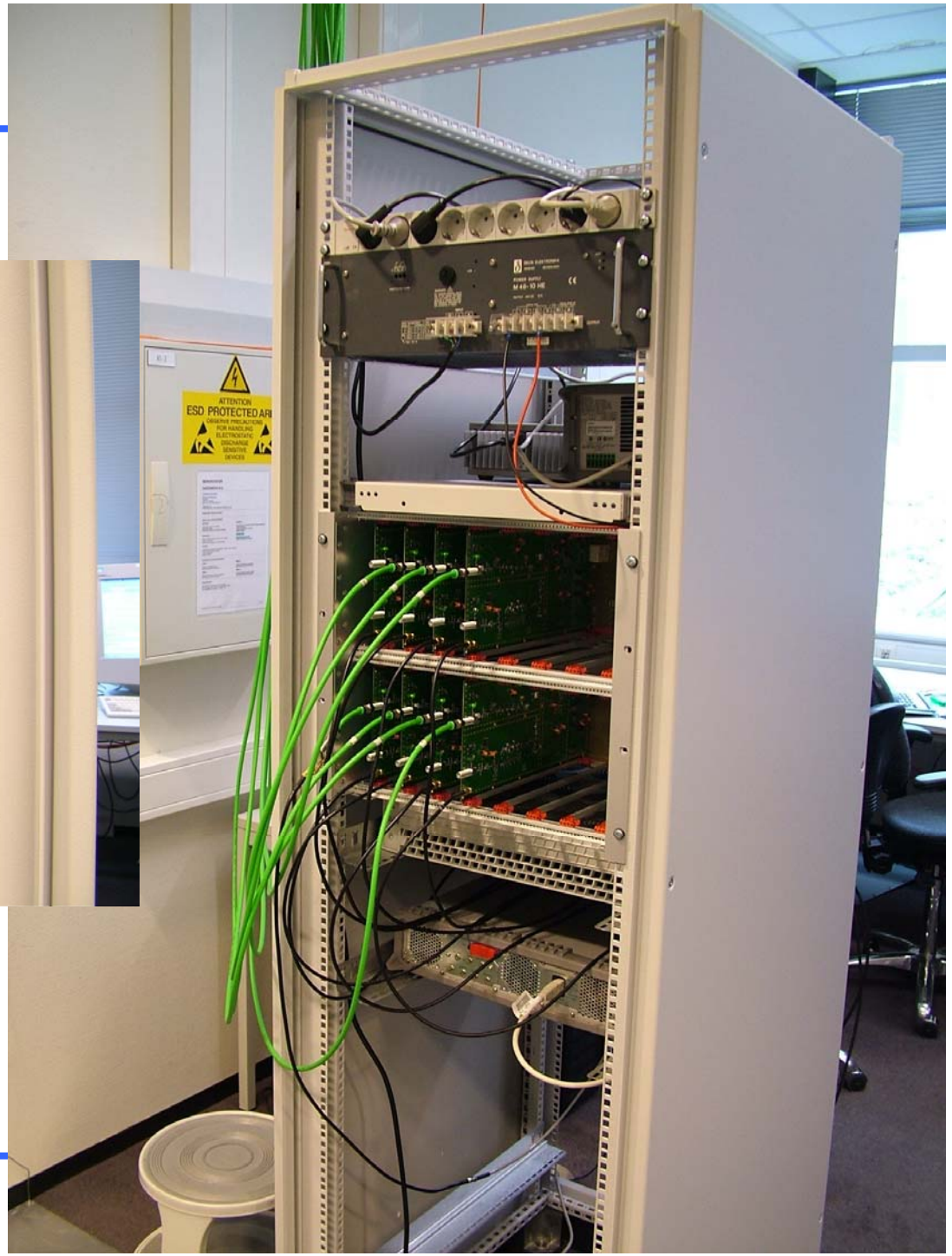
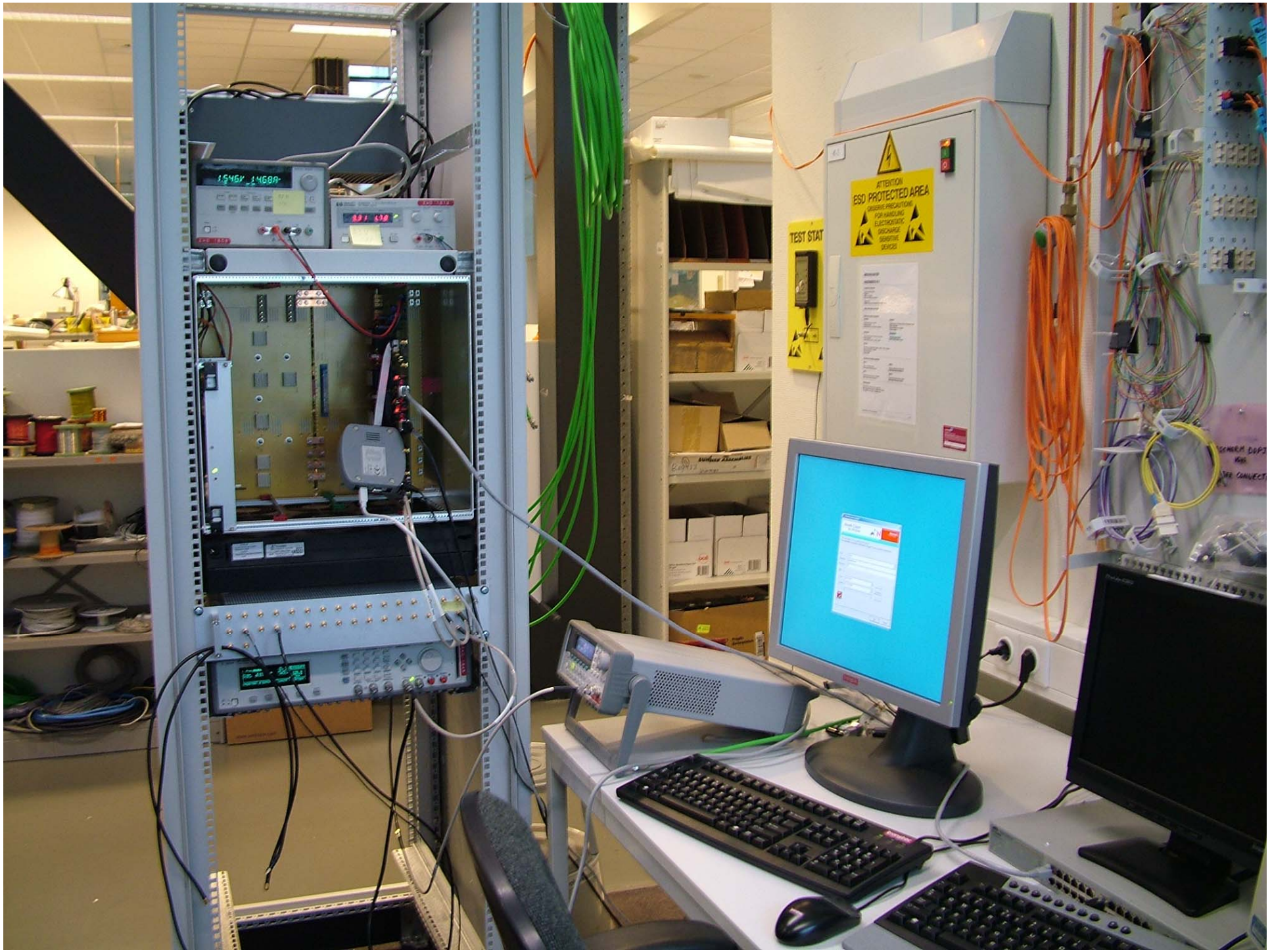
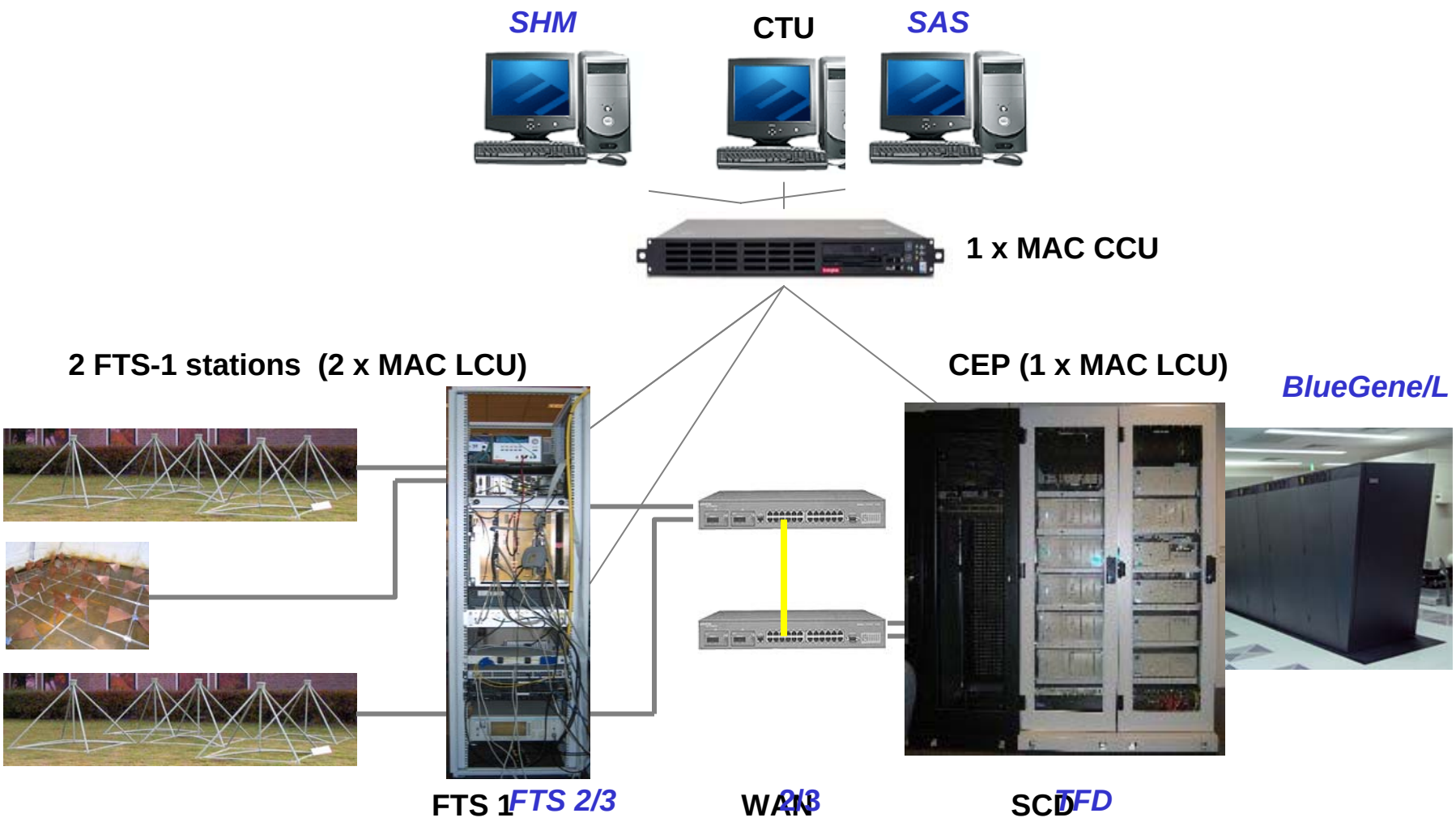
Status begin 2005



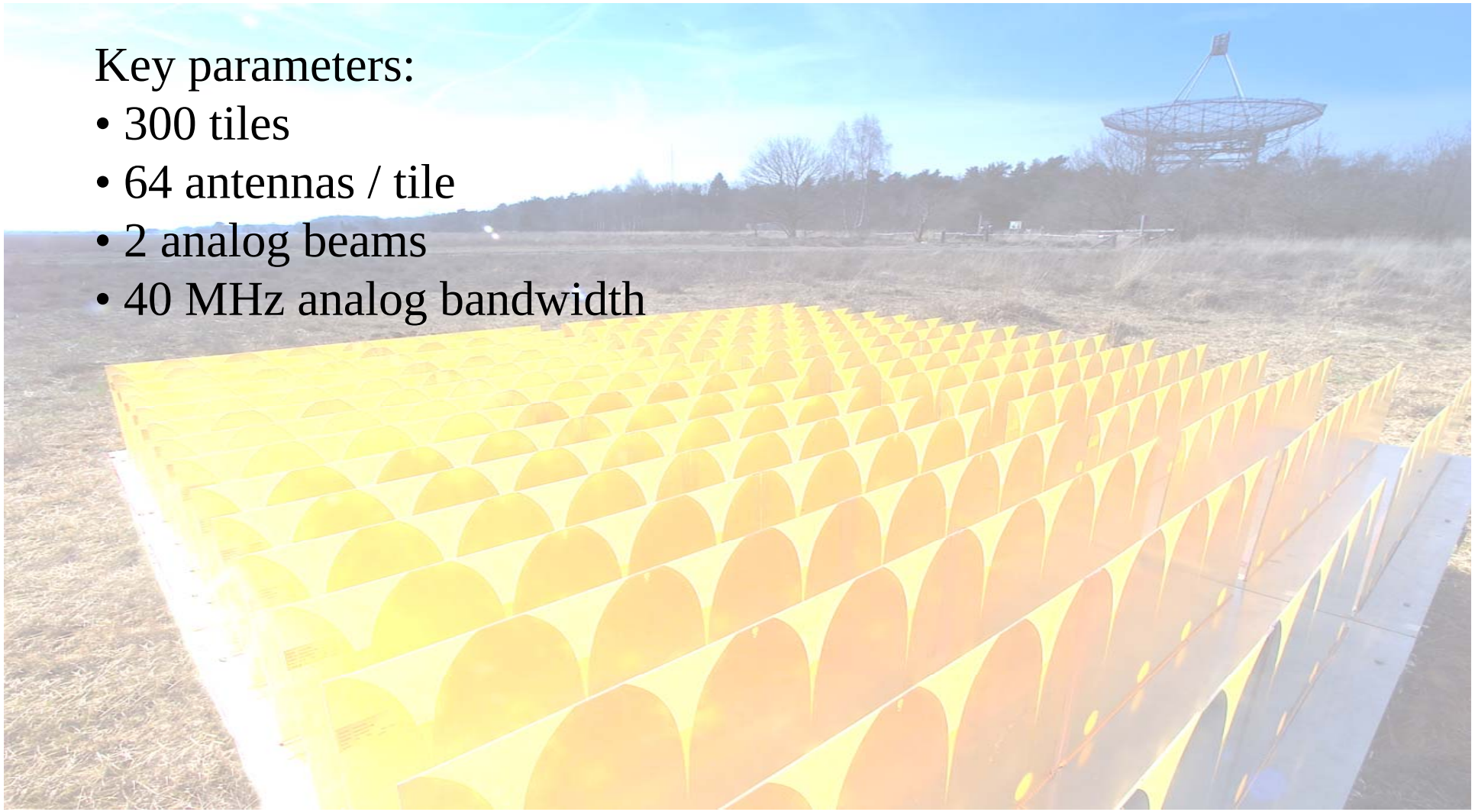

ATTENTION
ESD PROTECTED


ATTENTION
ESD PROTECTED AREA
OBSERVE PRECAUTIONS
FOR HANDLING
ELECTROSTATIC
DISCHARGE
SENSITIVE
DEVICES
TEST STAT

LOFAR Integration

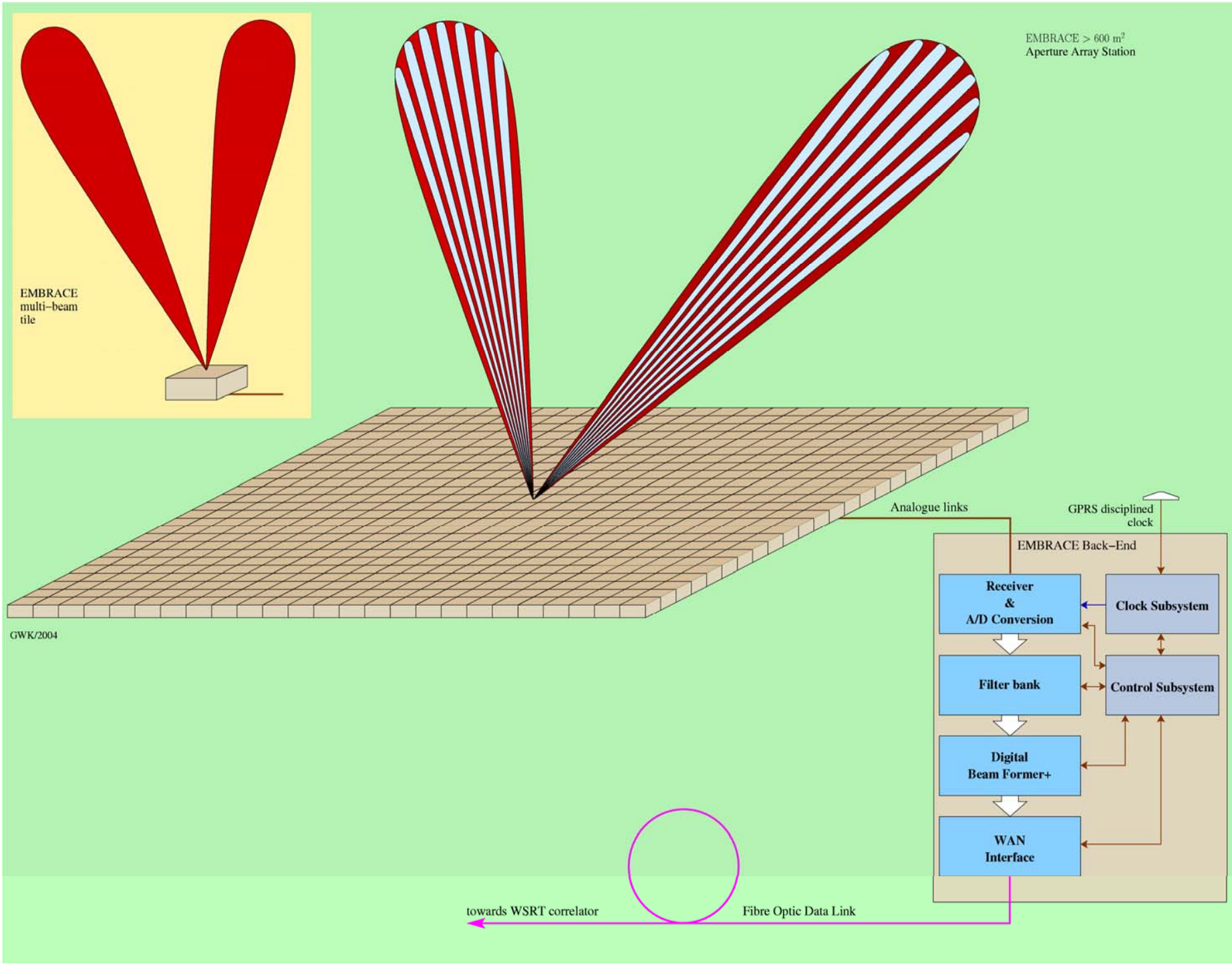


Embrace in a Nutshell



Key parameters:

- 300 tiles
- 64 antennas / tile
- 2 analog beams
- 40 MHz analog bandwidth


EMBRACE
multi–beam
tile
EMBRACE > 600 m²
Aperture Array Station
GWK/2004
Analogue links
GPRS disciplined
clock
EMBRACE Back–End
Receiver
&
A/D Conversion
Clock Subsystem
Filter bank
Control Subsystem
Digital
Beam Former+
WAN
Interface
towards WSRT correlator
Fibre Optic Data Link

- Hardware of a LOFAR station is re-used
  - stripped version
  - different receivers
  - 3 stations necessary
- WSRT correlator is used

- Digital circuits are stable (if you design it properly …)
  - temperature (within a given range)
  - components
  - time
- Digital signals can be copied without loss
- Digital signals can be controlled in a flexible way
- Doing it digital becomes cheaper

- Massive amount of data
  - number of signals (sensors) increase
  - number of bit to represent a signal increase
  - bandwidth of signals increase (ADC moves towards the antenna)
- Relative “simple” operations required (implementation is not)
  - filtering
  - beamforming
  - correlation
  - routing signals
  - …
- More flexibility required
  - exchange beams for bandwidth
  - select bands, signals, …

But, price per operation decreases …