



Beamforming techniques in Embrace and LOFAR

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& the EMBRACE & LOFAR teams



ASTRON Observing Facilities



Westerbork Synthesis Radio Telescope

Base line 3 km

14 telescopes



LOFAR (Low Frequency Array)

36 station of 864 dual polarization antennas

(96 low band and 48 High Band tiles)

+ 10 International Stations in Germany, Sweden, the UK, ...





R&D



New Concept being developed:

Embrace

Aperture Array

Apertif

Focal Plane Array for WSRT.

UniBoard

Multi FPGA processing platform for beamforming and correlation.

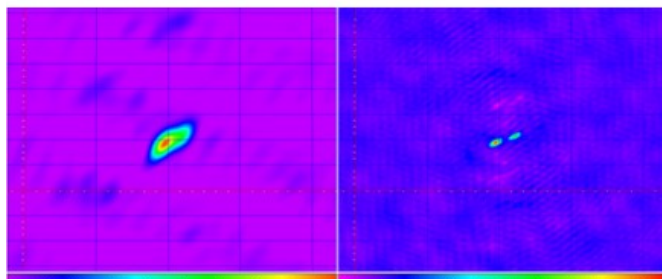
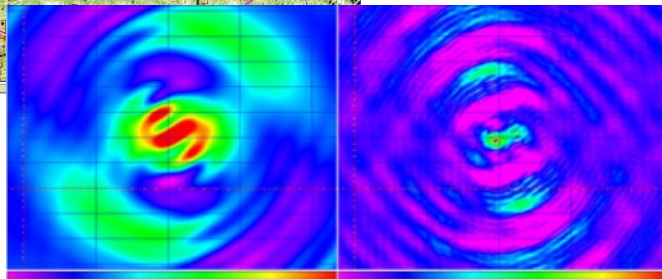
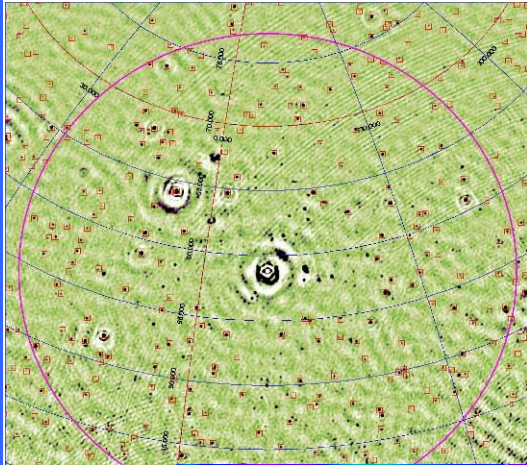
DARIS

Distributed Aperture Array for Radio Astronomy In Space



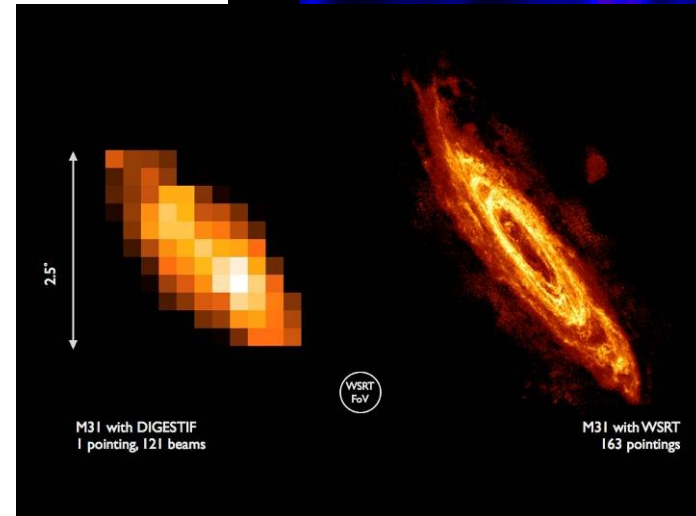
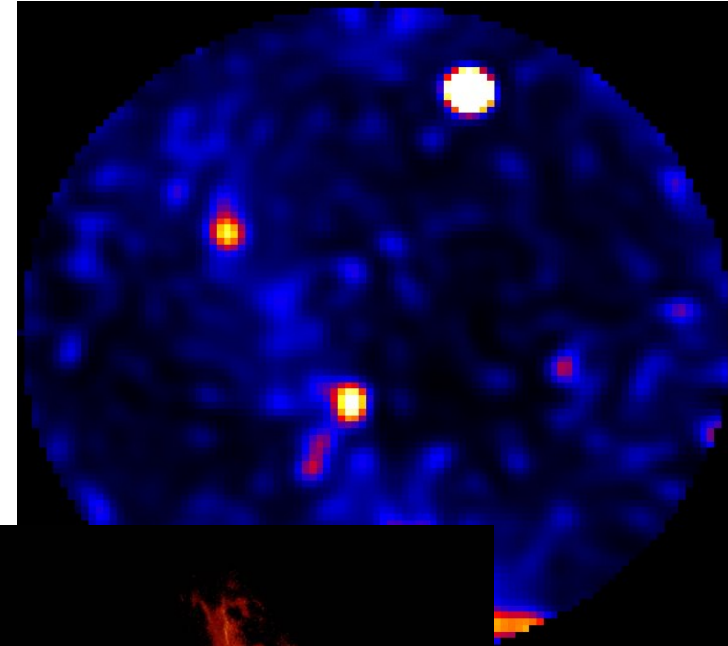


Results !



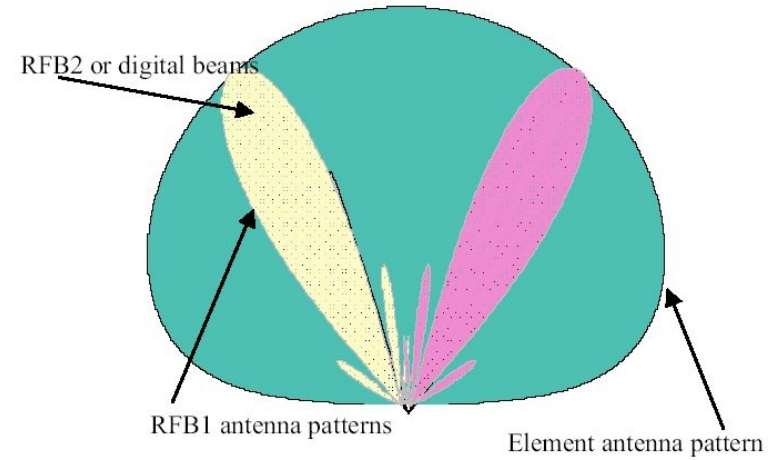
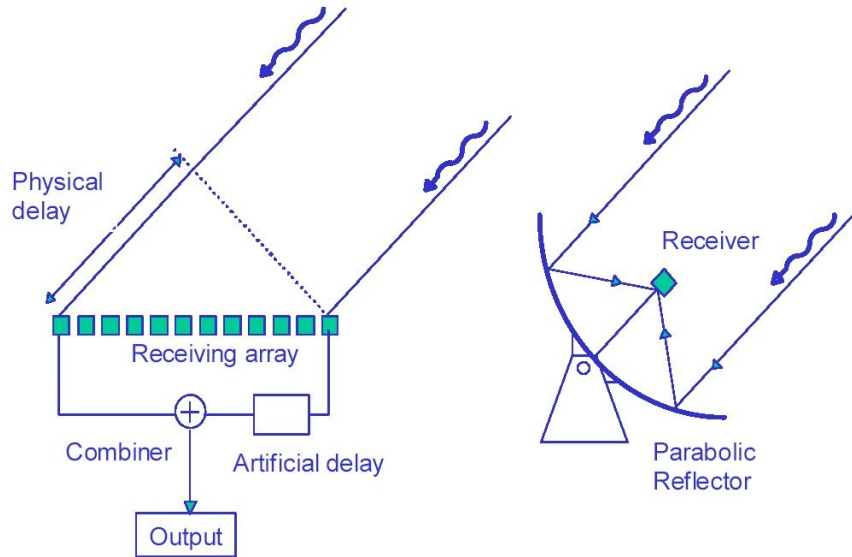
LBA 30 MHz

HBA 120 MHz



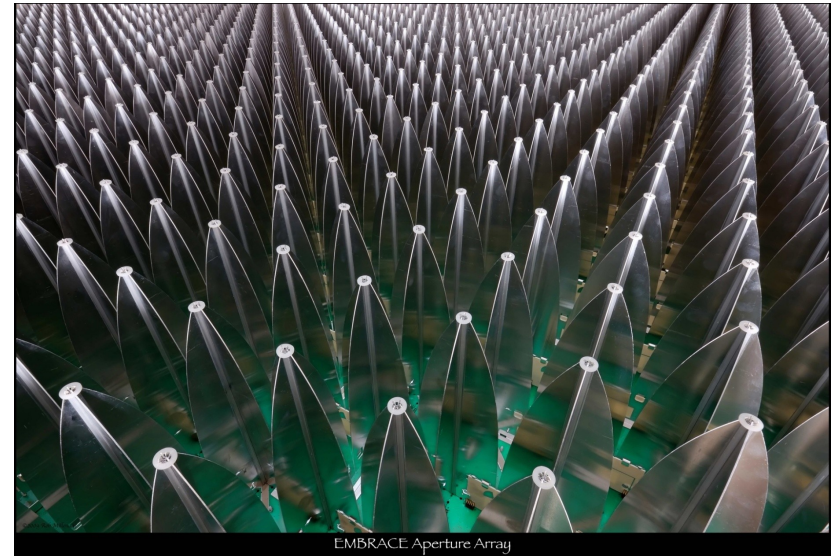


Phased Array Technology



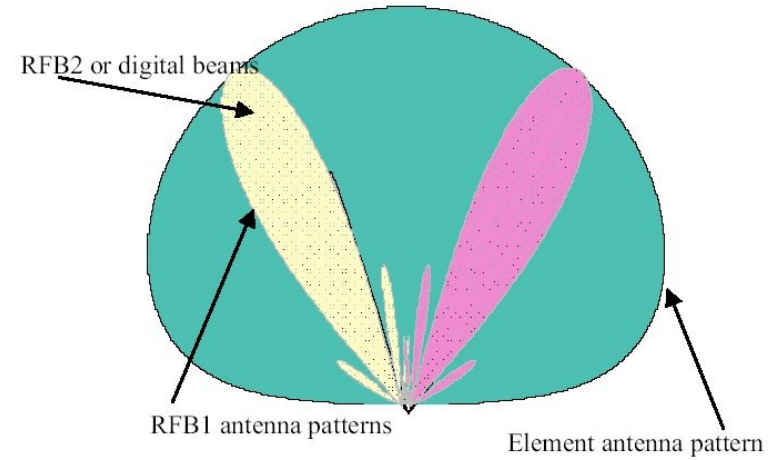
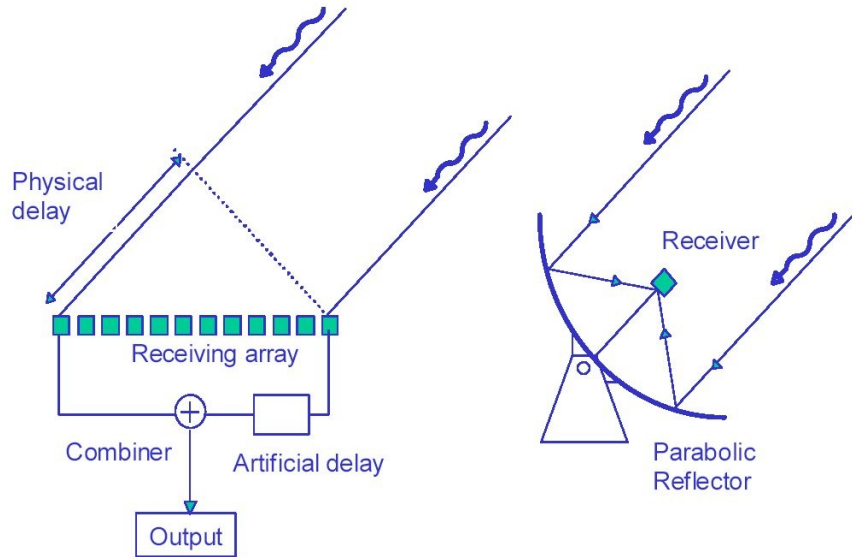


Aperture Arrays





Phased Array Technology



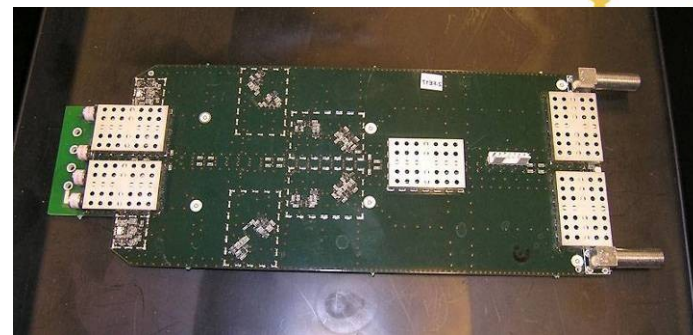
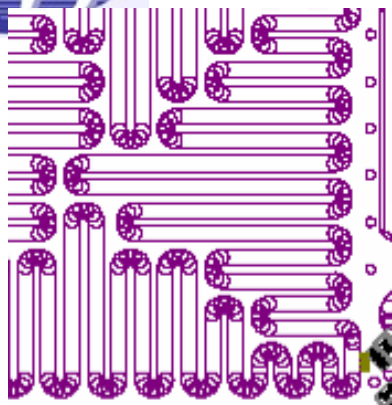


Beamforming

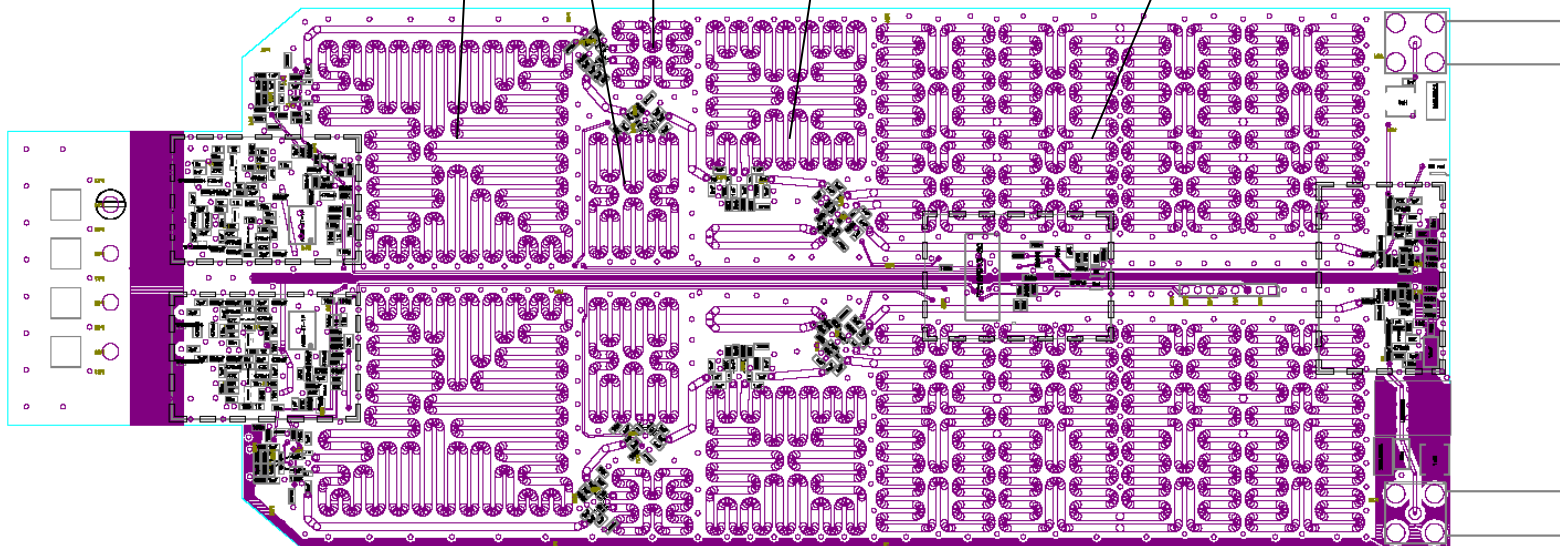
	LOFAR		SKADS
	Low Band	High Band	Embrace
Frequency	10-90MHz	110-240MHz	500-1500MHz
Max Element distance	85m	5m	1m
Analog Delay	-	True time	Phase and true time
Max Tile distance	-	38m	17m
Digital BW	195kHz	195kHz	195kHz
Digital Delay	Phase	Phase	Phase



High Band Antenna Front End Unit



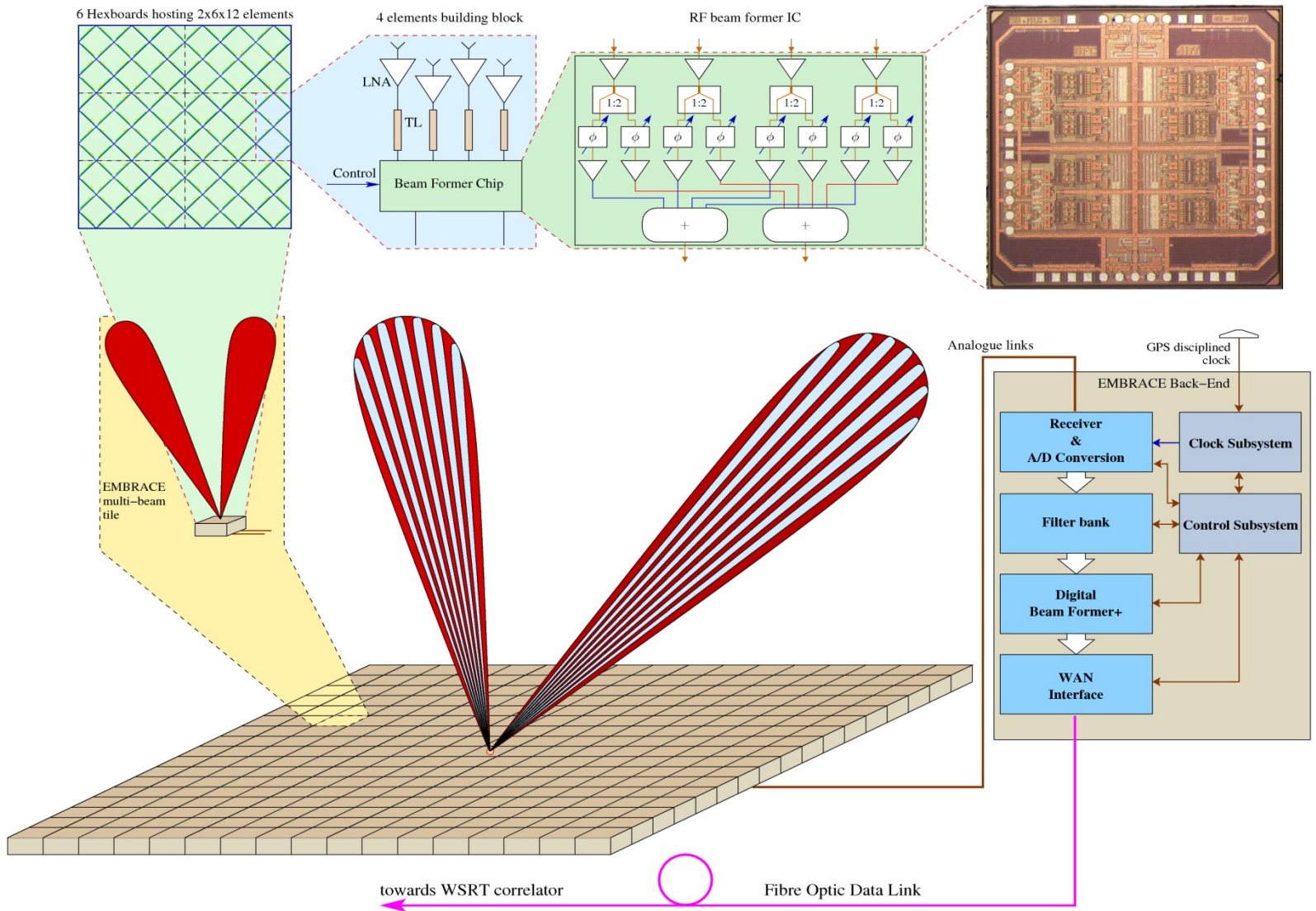
0.5 ns
1 ns
2 ns
4 ns
8 ns



PCB Klaas Dijkstra



EMBRACE Architecture overview





EMBRACE Requirements

Frequency range	500 MHz - 1500 MHz.
Polarisation	Single polarisation
Physical Collecting area	~300 m ² WSRT / 100 m ² Nançay
Aperture Efficiency	> 80%
Electronic Scan Range	+/-45 deg
T	<100K @ 1GHz (aim for 50K)
Element phase control accuracy	3 bit (also time delays)
Instantaneous bandwidth	40 MHz (Achieved >200 MHz)
Dynamic range A/D Converter	60dB (effective # of bits ~10)
Number of independent FoV (RF beams)	2
No of digital beams	8+



Building the platform infrastructure





Platform Specifications



- Platform @ WSRT installed wk 21
- Between RT4 and RT5
- Platform 20x22 m²
- Additional platform for back-end 4x8 m²



Site at Westerbork

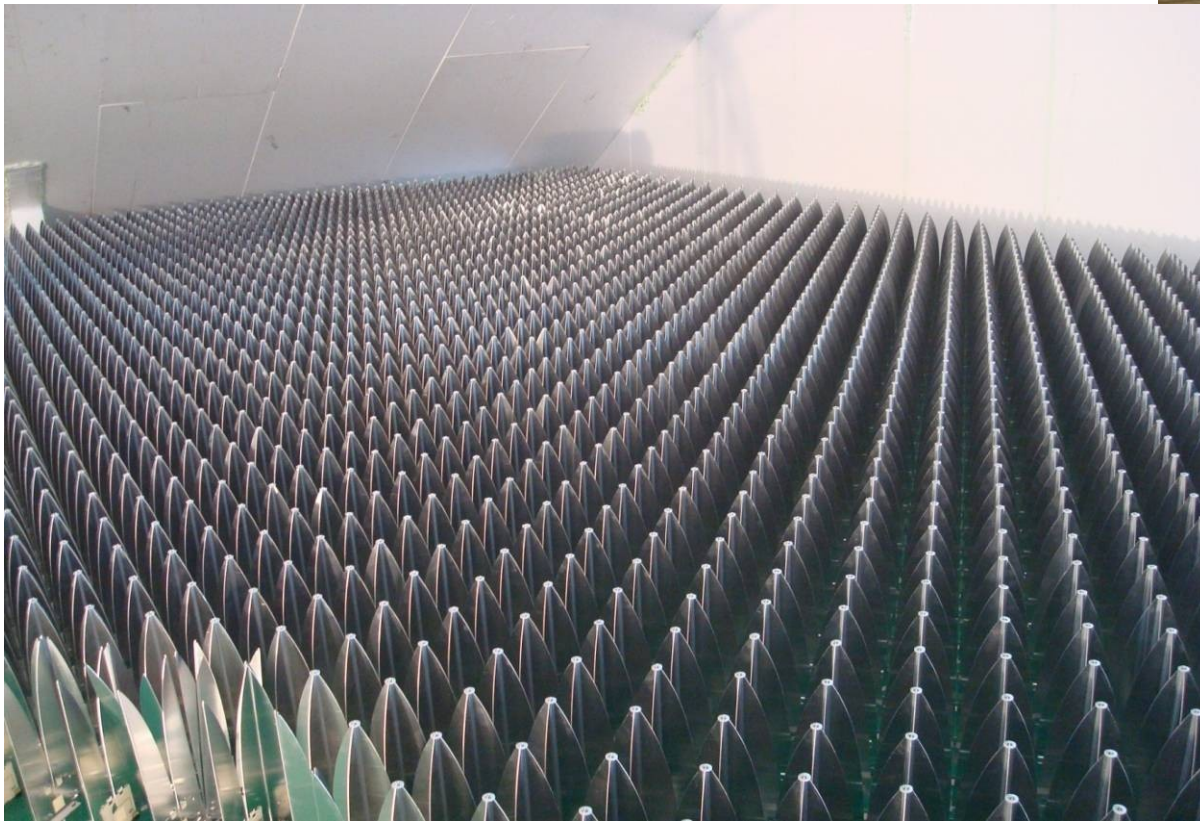


Radome : 17m x 17m x 4.7m



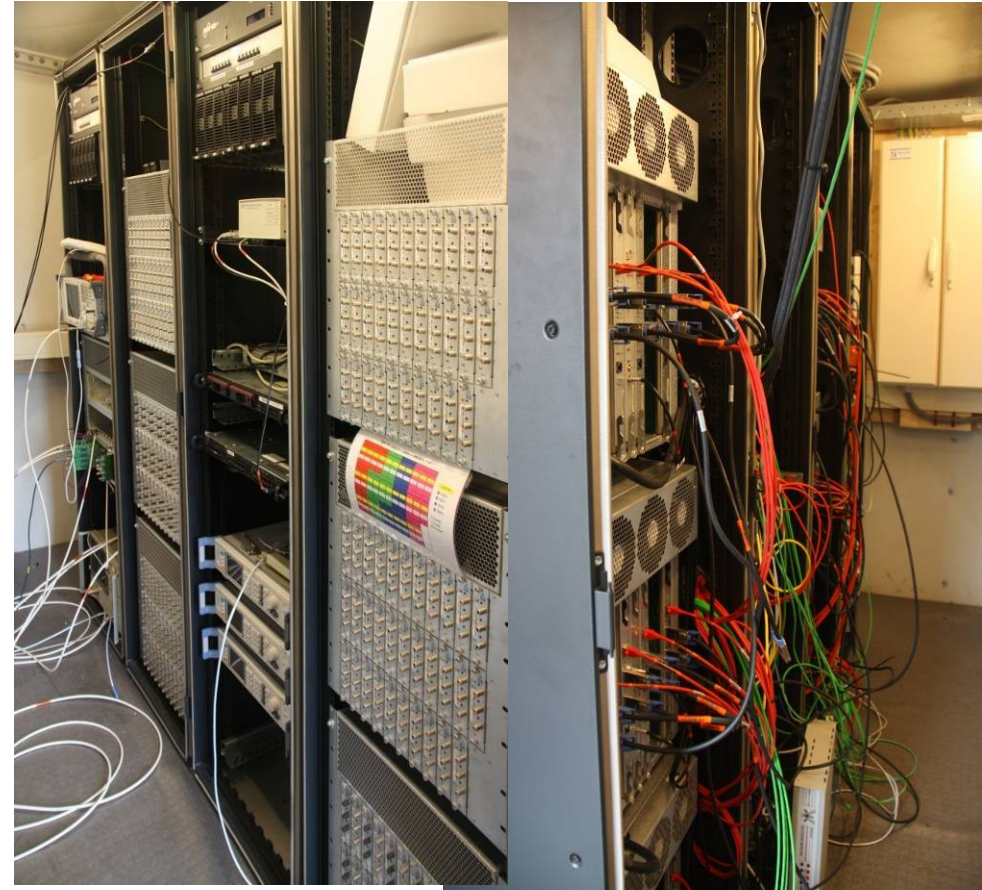
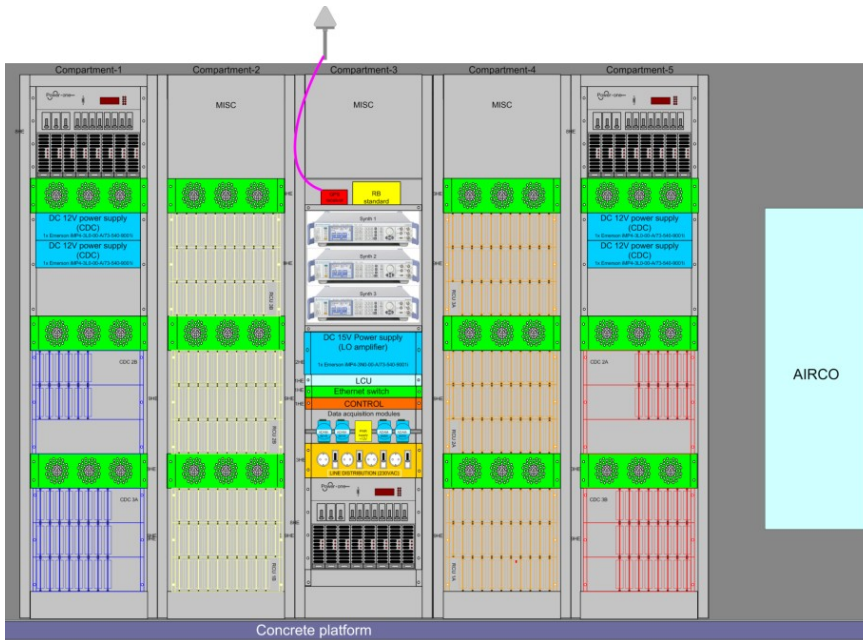


Radome and Array



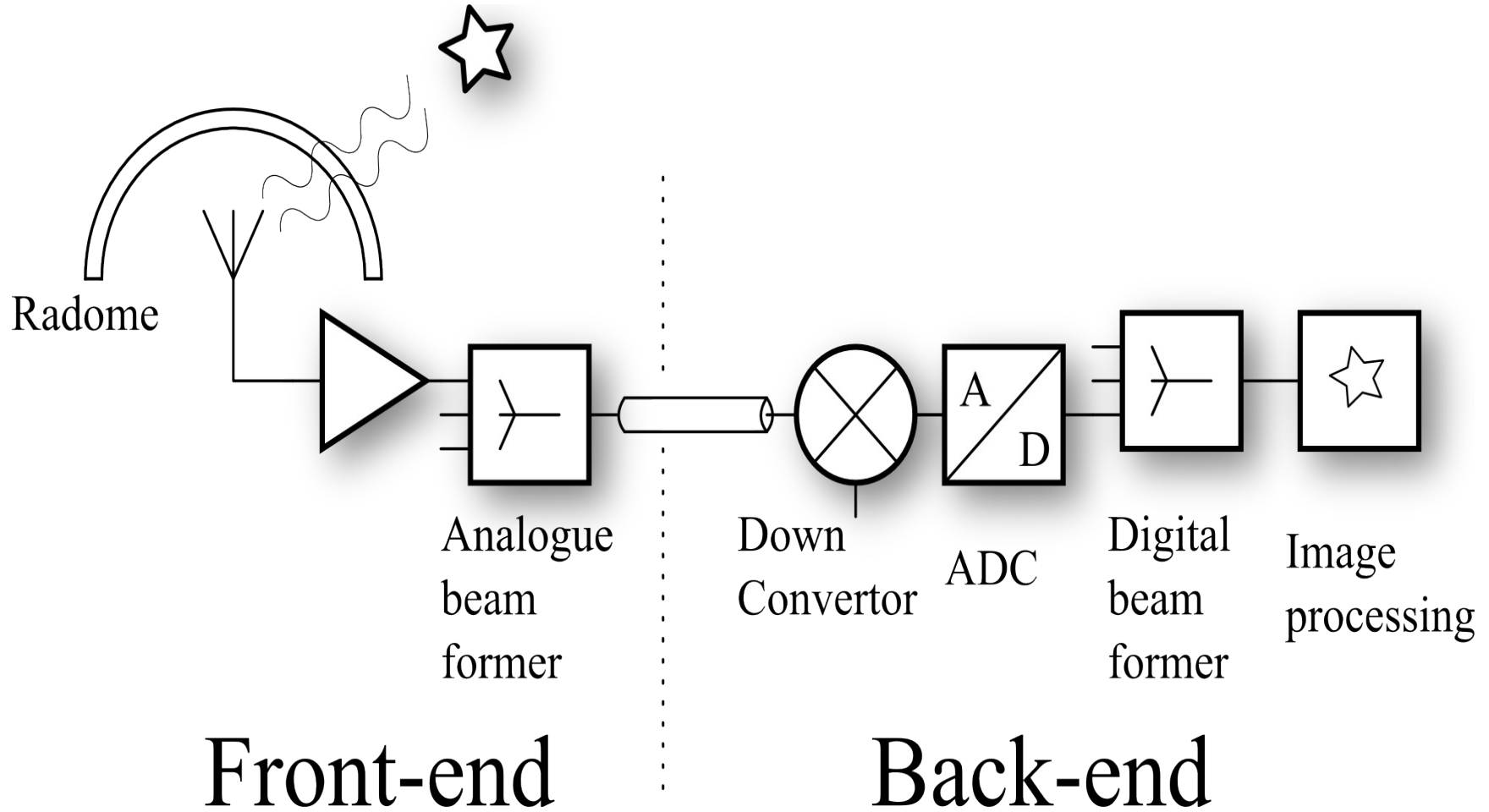


Back end processing



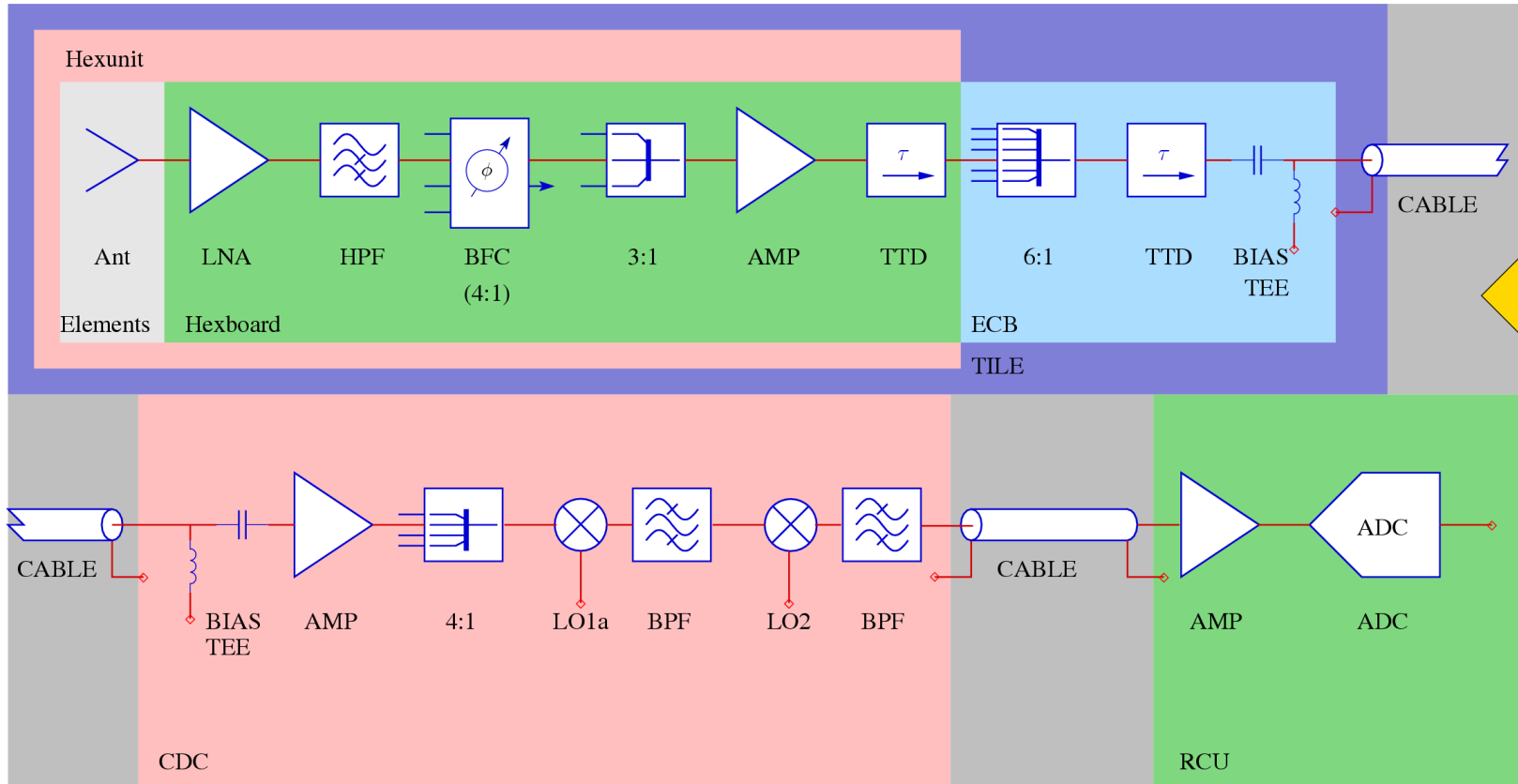


EMBRACE signal flow overview



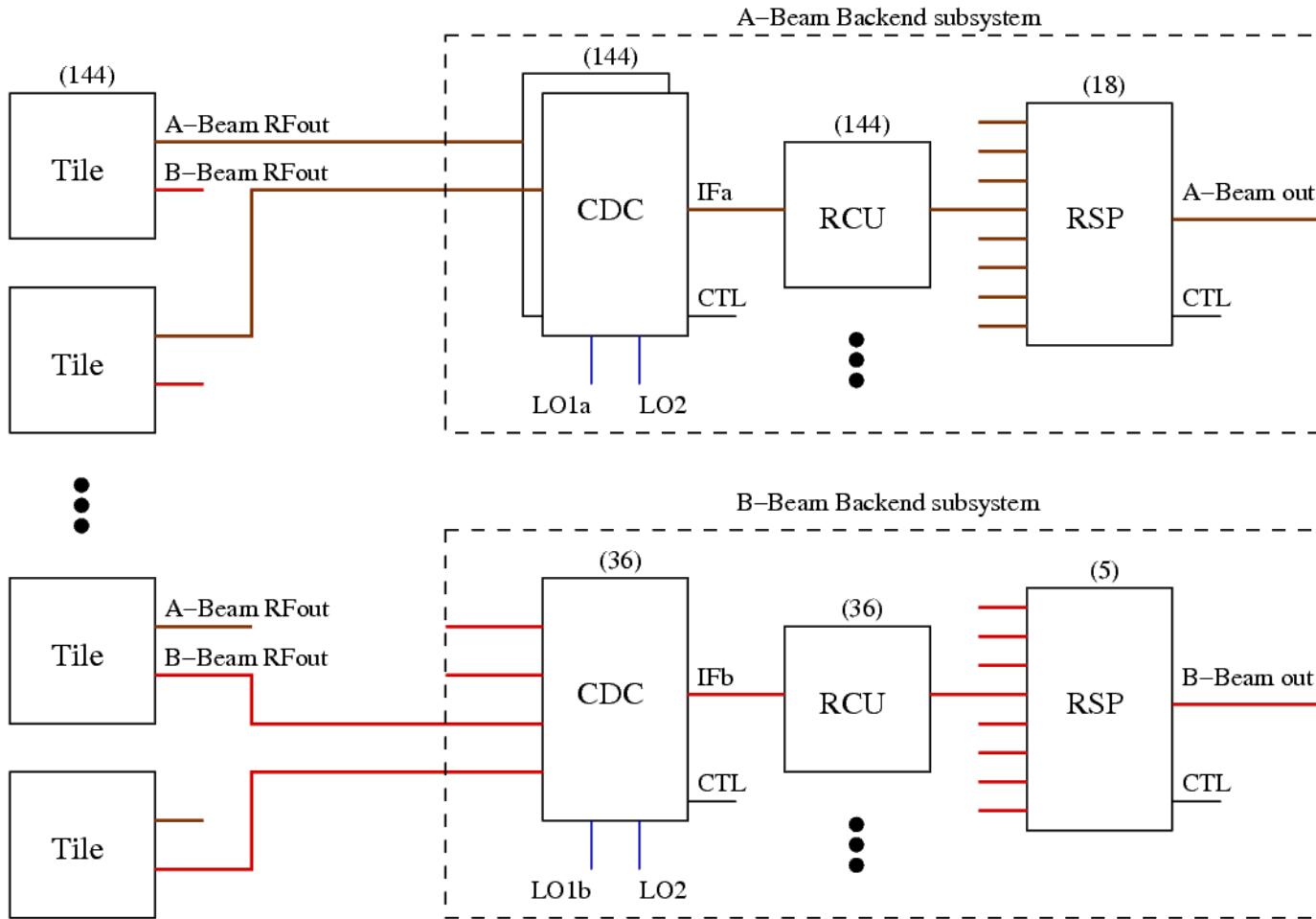


Block diagram signal flow





Architecture with numbers - WSRT station



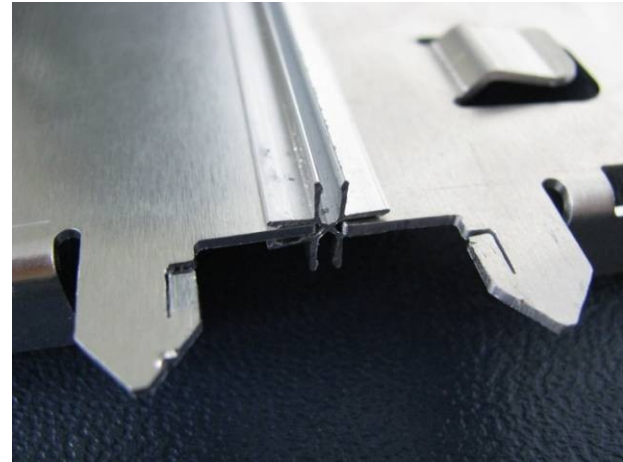
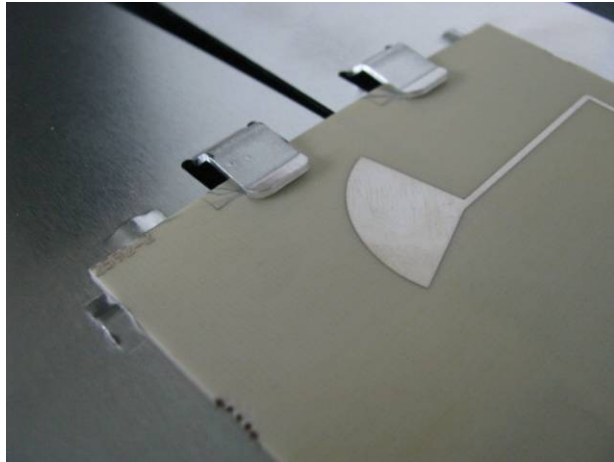
Beam A

One full FoV RF beam without combiner option in CDC

Beam B

RF beam with combiner option in CDC

Antenna development

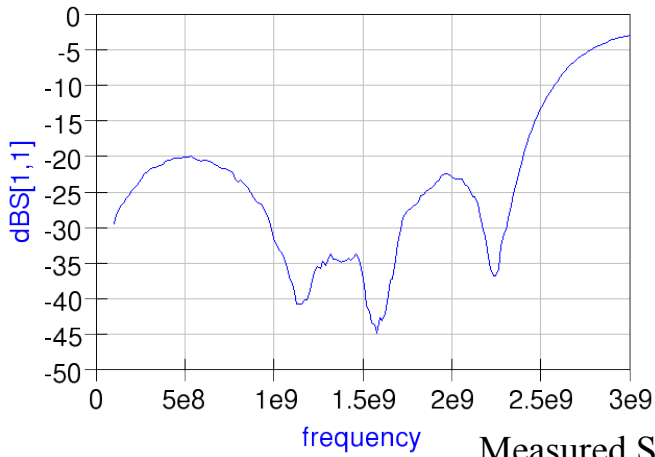
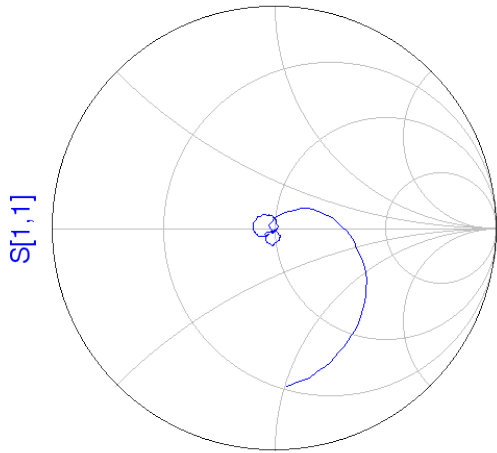


- Mechanics evolved toward trustworthy and producible antenna element.

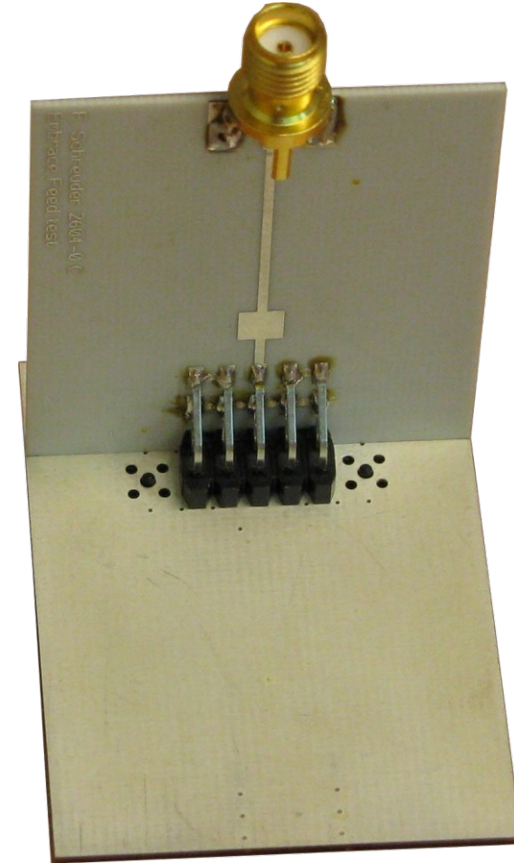
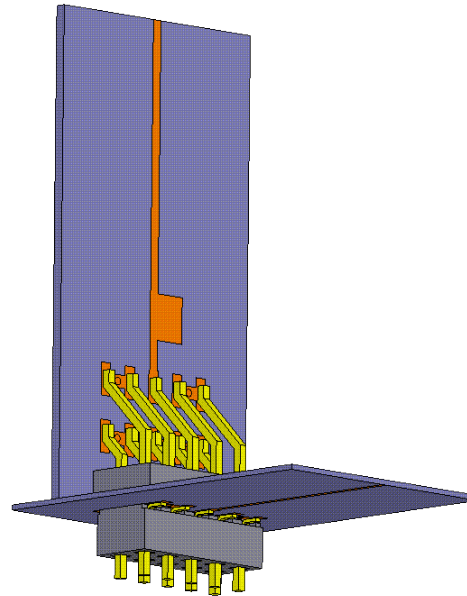


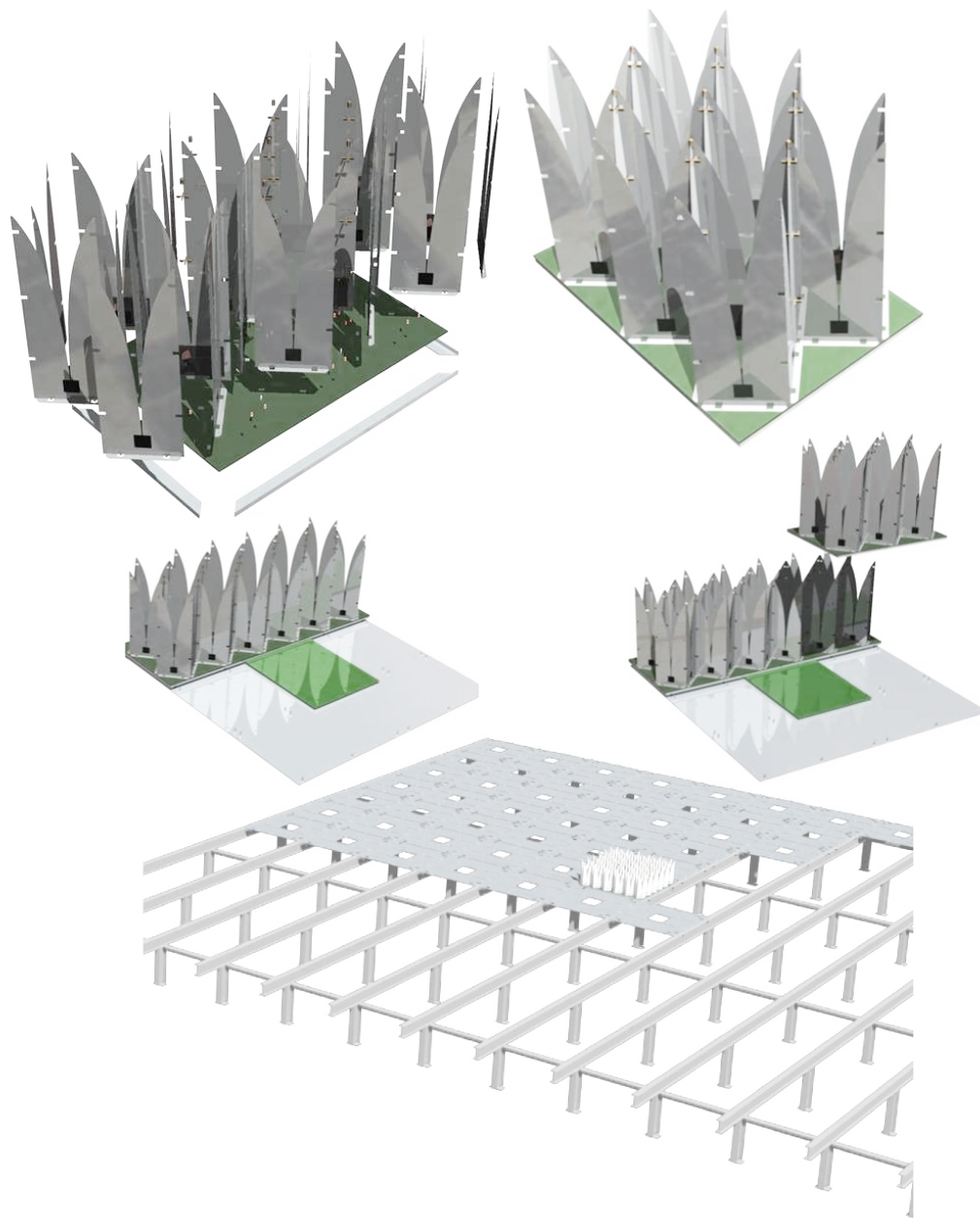
Embrace antenna feed connector

Test PCB



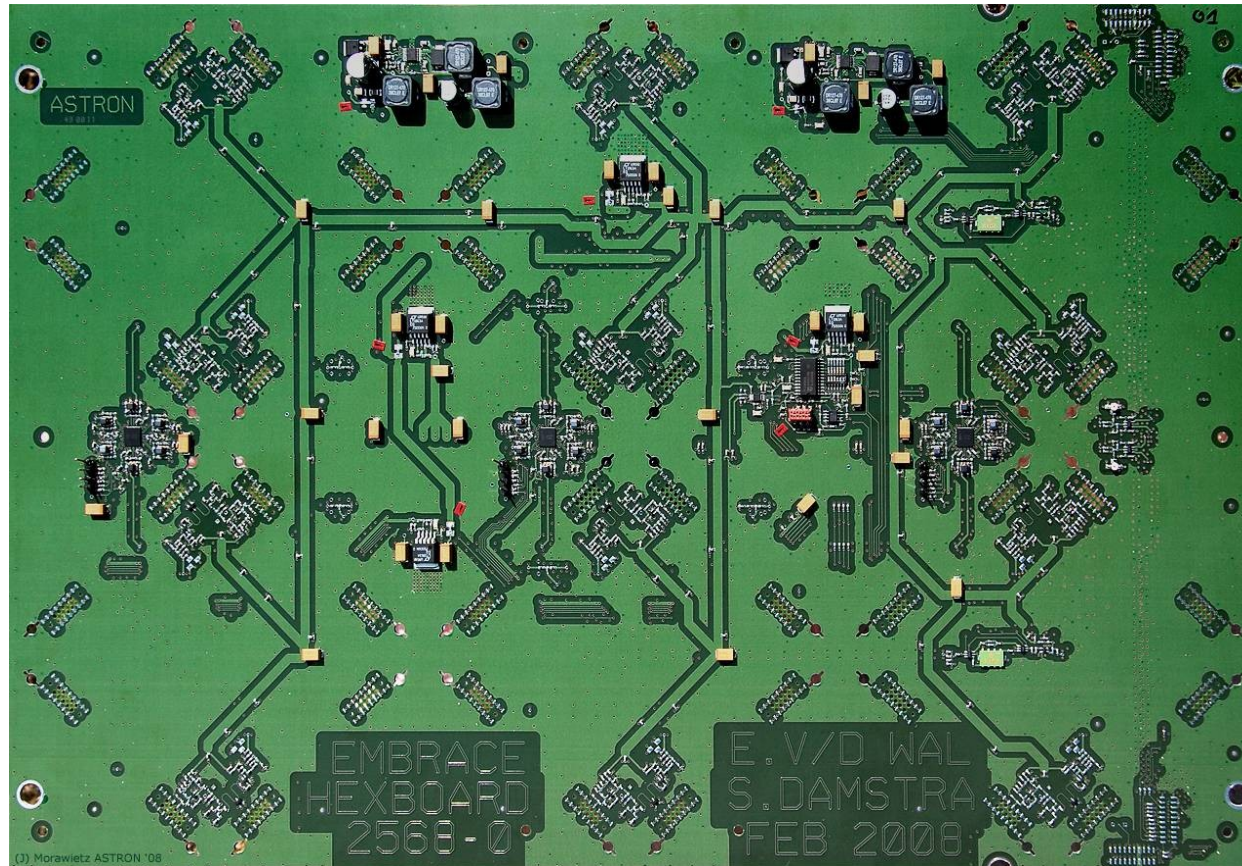
HFSS Model





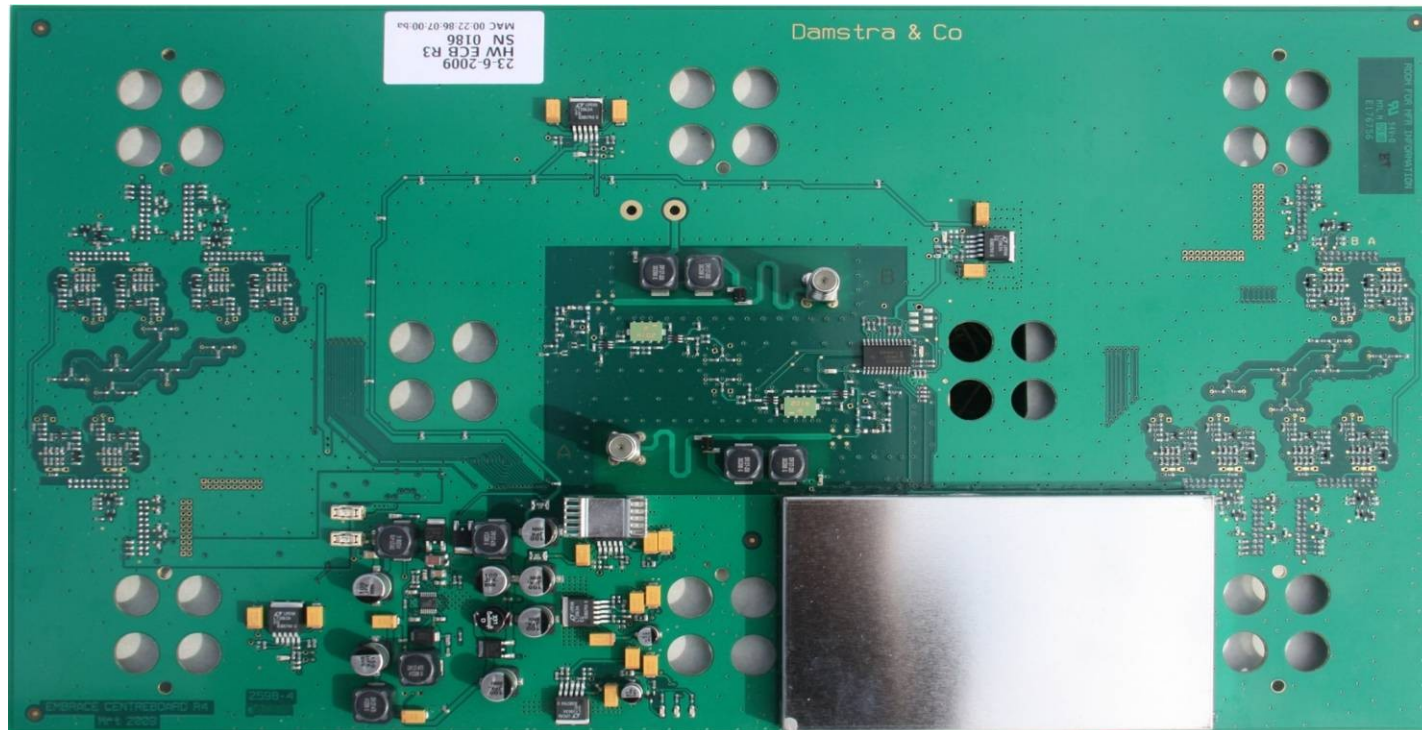
Mechanical break down
of EMBRACE array

Hex-Board



- 12 analog RF channels; phase and amplitude controllable
- Bias conversion and distribution
- Temperature monitoring
- Time delay

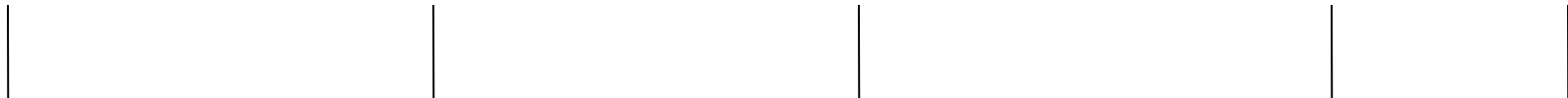
Centre-Board



- Analog summation for two beams
- Time delay
- Bias distribution
- Ethernet control



Control & Down Conversion Unit



48V DC Bias

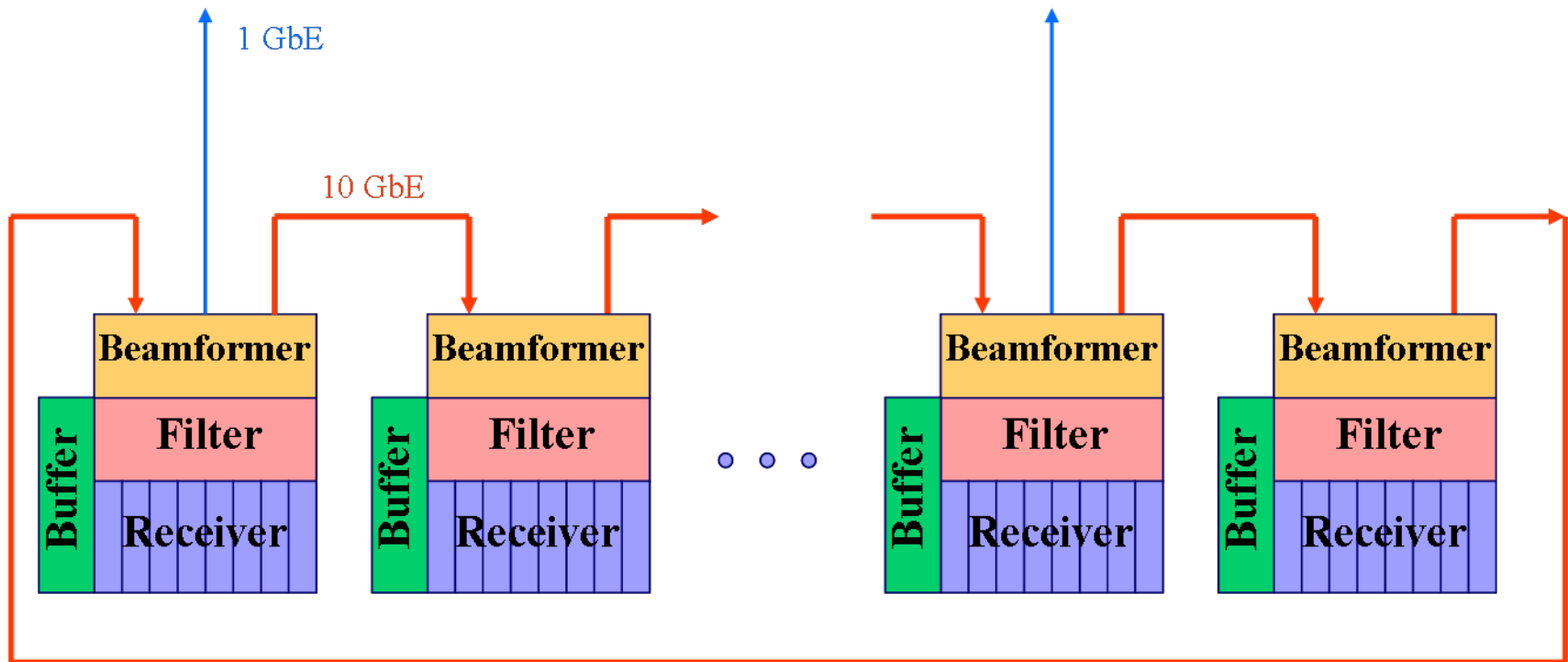
Control

Filter

Down
conversion

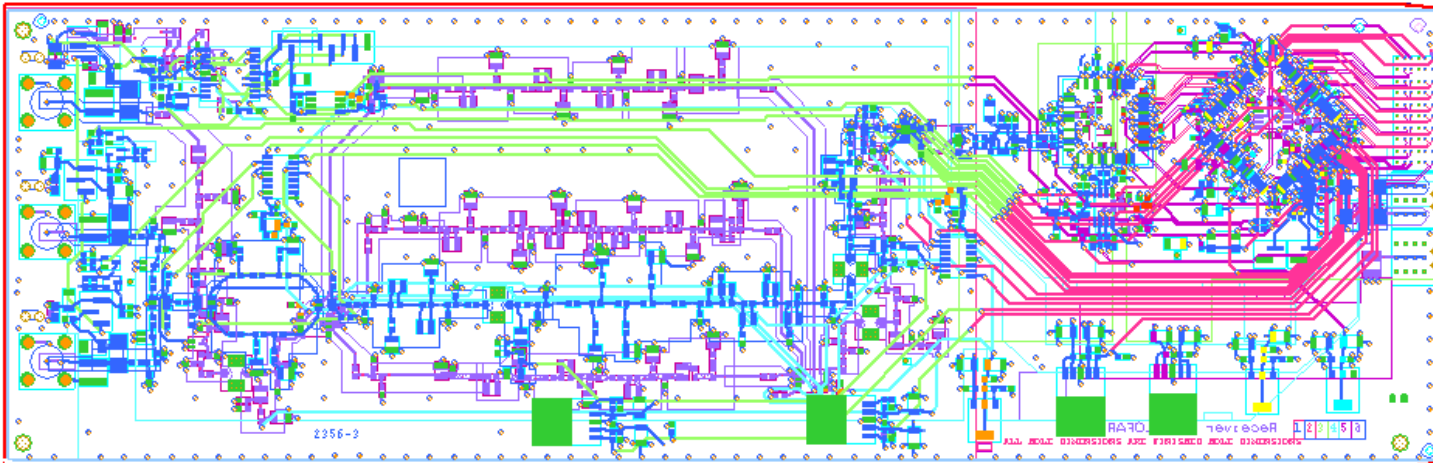
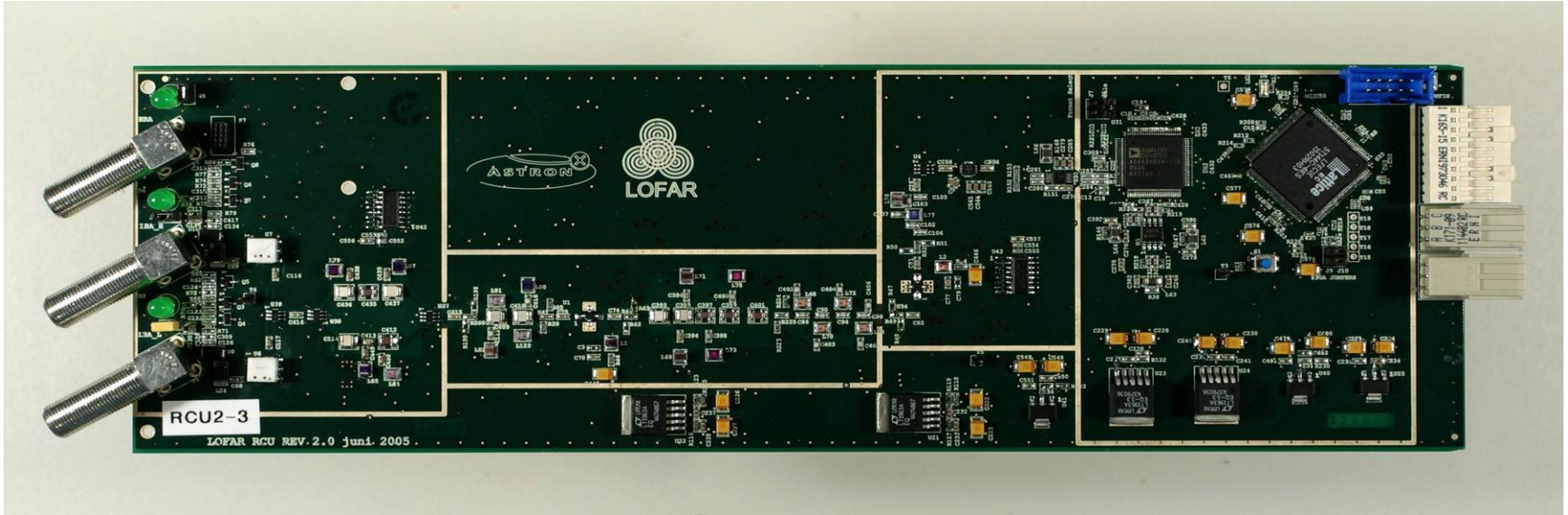


Embrace Backend Block Diagram



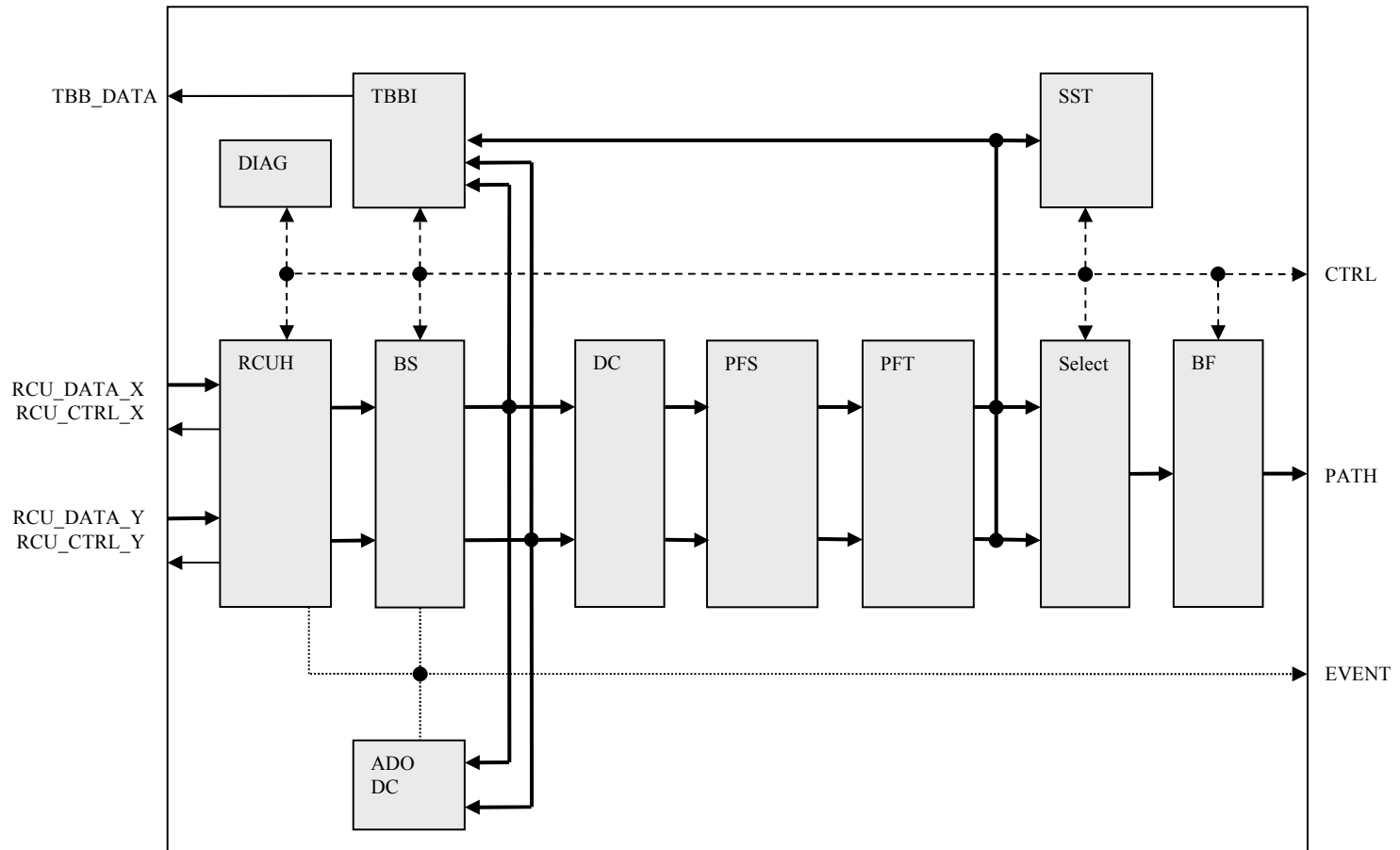


Receiver Unit (RCU)

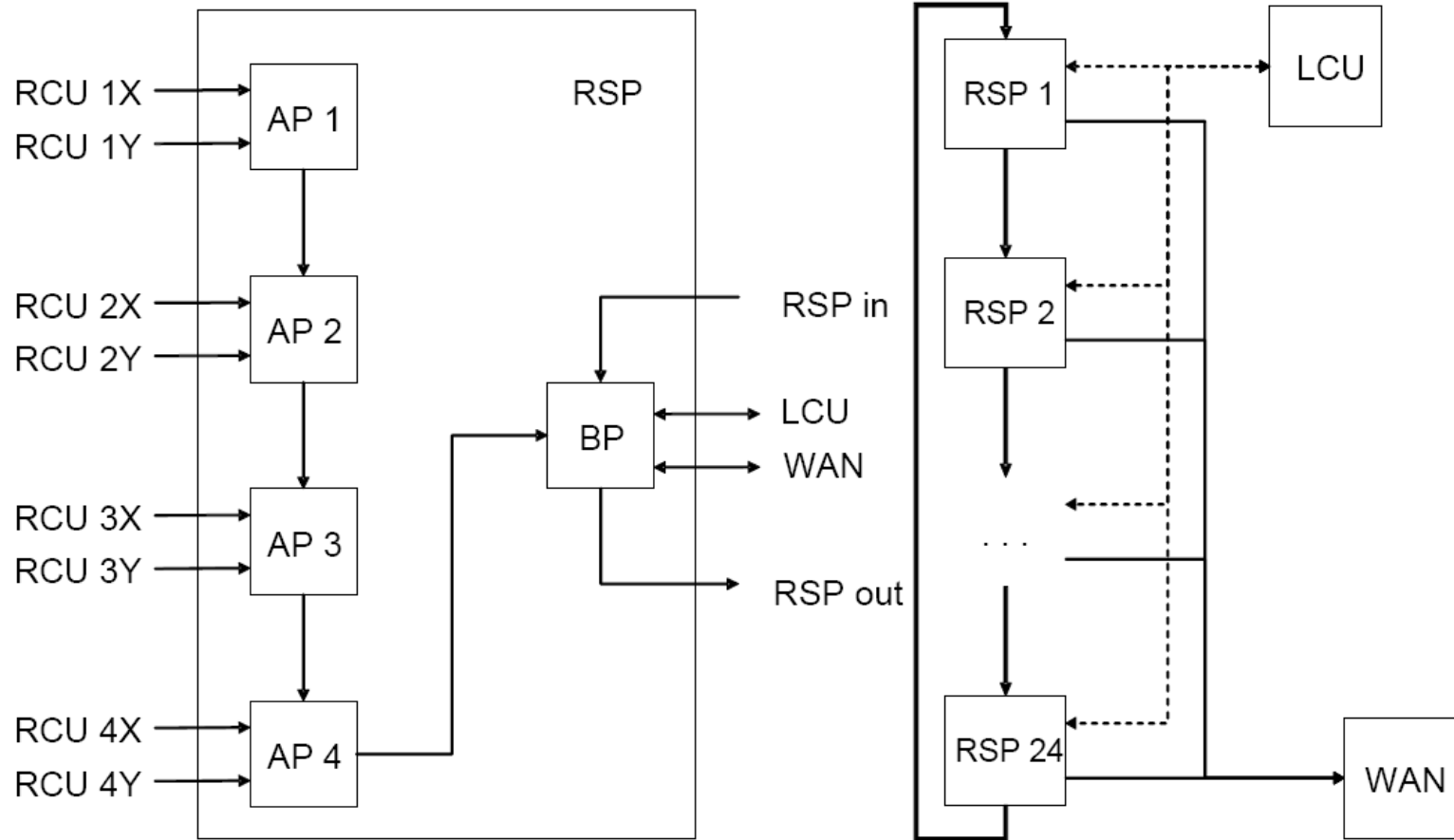




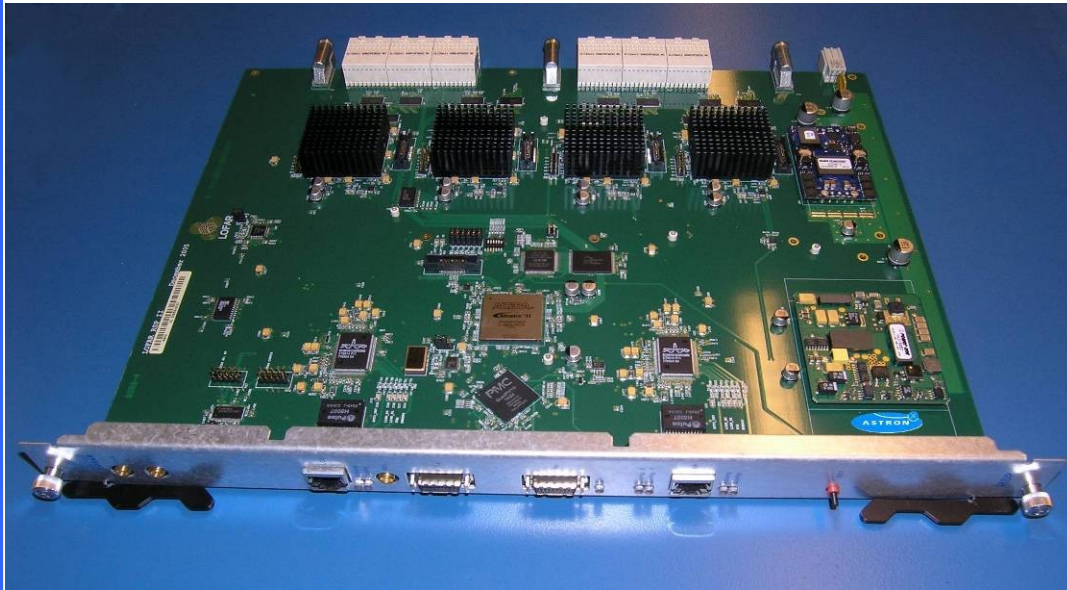
RSP Beamformer



RSP-Boards in a System



Digital Processing Board



24 Processing boards are needed to combine 144 Tiles.

RSP Beam former board

4 Xilinx Virtex 4 SX35 FPGA with each 192 DSP Slices

200MHz clock rate

12 bits input

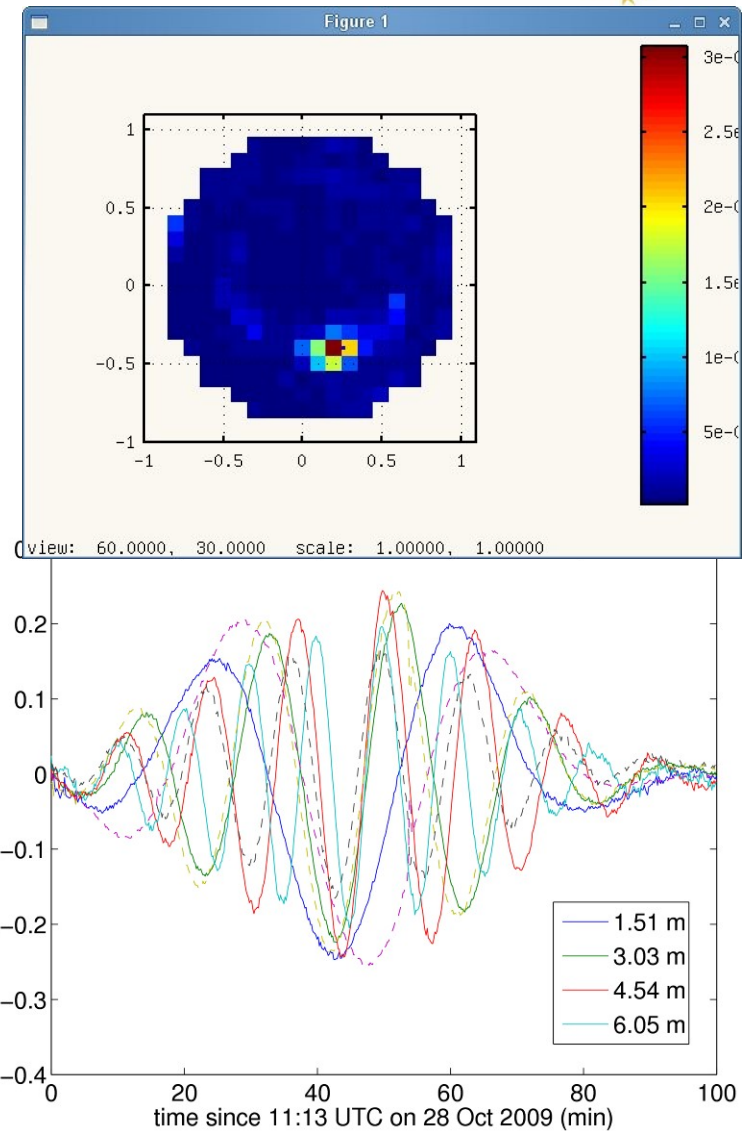
56 256kHz beam formed frequency channels at the output



Conclusion



- EMBRACE testing is ramping up
 - Half station hardware installed (Westerbork)
 - 40 tiles are ready to be shipped to Nancay
 - First results show the full signal chain is functional
- EMBRACE will deliver a phased array with more than 10000 elements
- A movie on the building of EMBRACE will be shown during the break





ASTRON



Unité Scientifique de Nançay



Max-Planck-Institut
für
Radioastronomie

