The UniBoard

a RadioNet FP7 Joint Research Activity

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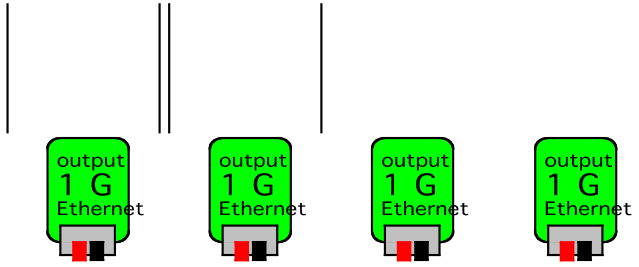
Overview

- Background, project setup
- Current state
- UniBoard as SKA phase 1 correlator/beam former
- Future: UniBoard²

The aim

- Creation of a multi-purpose scalable l performance computing platform for r astronomy
- Originally proposed by Sergei Pogreb late 90s, as a single-board all-station correlator, became basis of project in
- Combine as much CPU and as much possible on a “reasonably” sized boa (Pogrebenko melt-down criterium)
- Use standard interfaces as much as p
- Only digital, nothing analog...
- Develop several different applications time, force design to be as generic as



RadioNet

EC contract nr 227290

The project

SKA SQUARE KILOMETRE ARRAY

- **UniBoard: a RadioNet FP7 Joint Research Activity**, 9 partners, kicked off January 2009

- **JIVE**: project lead, VLBI correlator
- **ASTRON**: hardware development, test firmware
- **INAF, University of Bordeaux:** digital receiver
- **University of Manchester:** pulsar binning machine
- **University of Orléans:** RFI mitigation algorithms
- **KASI**: VLBI correlator

- **ShAO:** digital receiver, VLBI correlator
- **University of Oxford**: all-dipole LOFAR correlator

- Strong support from collaboration, large amount of matching effort, financial contribution

Jodrell Bank Observatory

IRAM

jive

KOSMA

l'Observatoire de Paris

Science & Technology Facilities Council

INAF

FG IGN

ESO

ASTRON

Max-Planck-Institut für Radioastronomie

mecso

SKA RON

CCLRC

JCMT

UNIVERSITY OF OXFORD

TKK

KASI Korea Astronomy and Space Science Institute

TU Delft

SEVENTH FRAMEWORK PROGRAMME

IAF Institut Angewandte Festkörperphysik

THE UNIVERSITY of NEW ORLEANS

VENTSPILS AUGSTSKOLA

UNIVERSITY OF CAMBRIDGE

tele

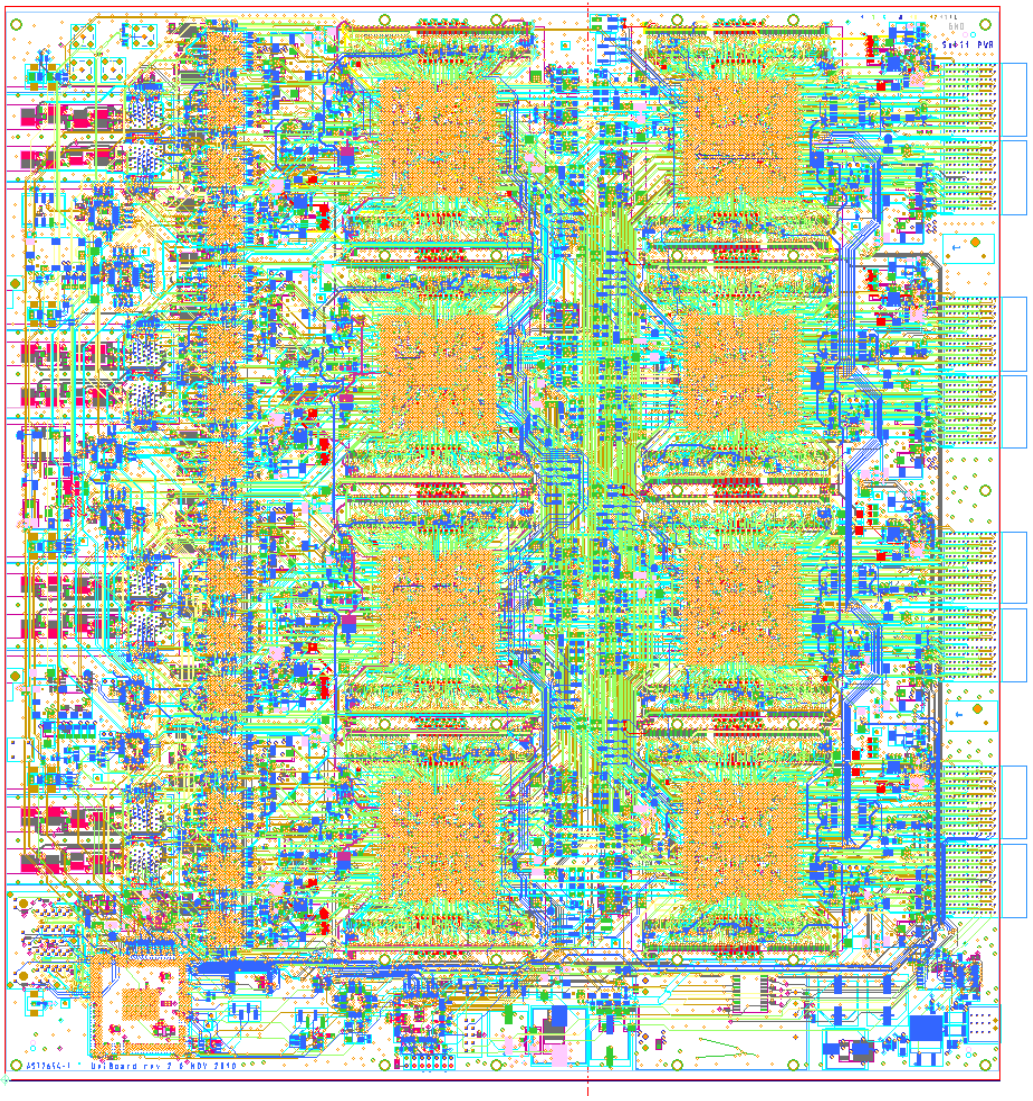
NRAO

Supporting projects

- ExBox: Expandable Box for X-correlation
  - JIVE/ASTRON proposal to NWO
- Build prototype FPGA EVN/APERTIF correlator
  - Using LOFAR expertise and technology
  - Backplane with several boards
  - Matching funds for UniBoard
- NWO - ShAO collaborative agreement
  - Stimulate collaboration between JIVE and ShAO in the development of FPGA-based correlators and VLBI space science applications
  - Several positions: students, postdoc, engineer

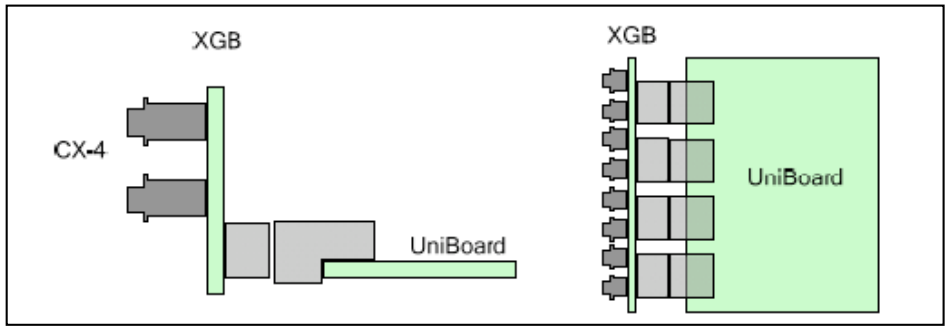
The design

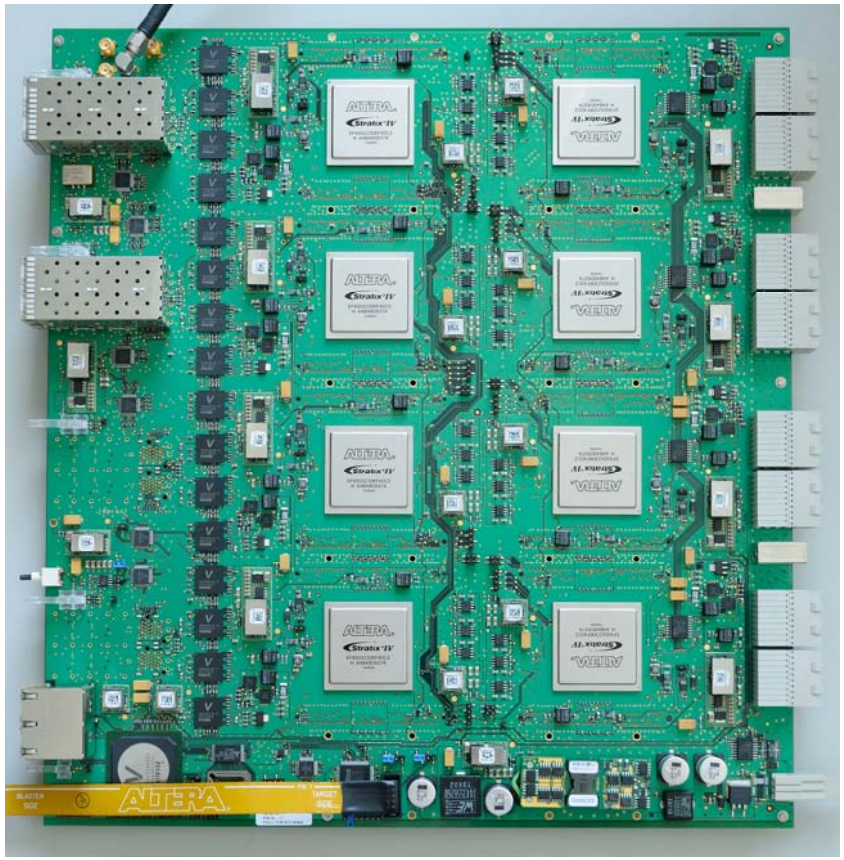
- 14 Layers
- 340x366mm
- 7304 components (47% of board space in use)
- 25798 connections
- 271 meter traces



The result

- Per board: 8 Altera Stratix IV FPGAs (40 nm,1288 18x18 multipliers, 400MHz, ~0.5TMAC/s)
- Per FPGA: 2 DDR3 memory banks (on backside of board)
- Four times four 10-GbE links connect to the front nodes via four SFP+ cages
- high speed mesh connects each front node to all back nodes
- The back nodes in their turn connect via four times four 8-bits LVDS to a backplane connector
- a 10G break-out board (the XGB) has been designed in the form of a mini-backplane, with a total of 16 CX4 connectors
- Prototype delivered May 2010, production run completed





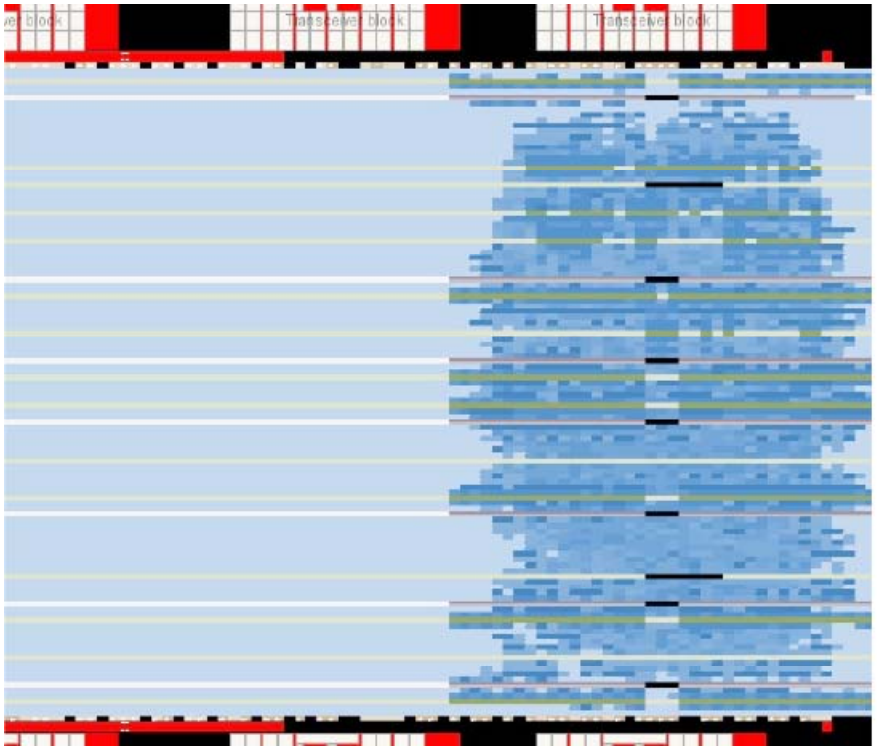
Applications under development

- **Currently under development**:
  - VLBI correlator (JIVE)
  - digital receiver (INAF, BORD)
  - pulsar binning machine (UMAN)
  - RFI mitigation (UORL)

- **Coming soon**:
  - APERTIF correlator (ASTRON)
  - APERTIF beam former (ASTRON)
  - AARTFAAC all-dipole LOFAR correlator (ASTRON + University of Amsterdam)
  - all-dipole LOFAR correlator (Oxford)
  - ShAO 65 meter telescope backend
  - Chinese/Korean VLBI correlators
  - more applications on the way

Current effort in Dwingeloo

- Hardware design: Gijs Schoonderbeek, Sjouke Zwier
- Test firmware (+ testing): Eric Kooistra, Daniel van der Schuur, Jonathan Hargreaves
- Board control, correlator control system: Harro Verkouter, Des Small
  - Written in Erlang
- VLBI correlator firmware: Jonathan Hargreaves, Salvatore Pirruccio, Jintao Luo



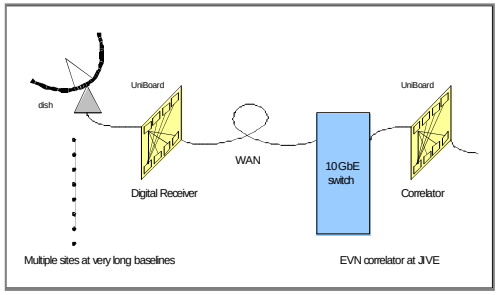
Different configurations

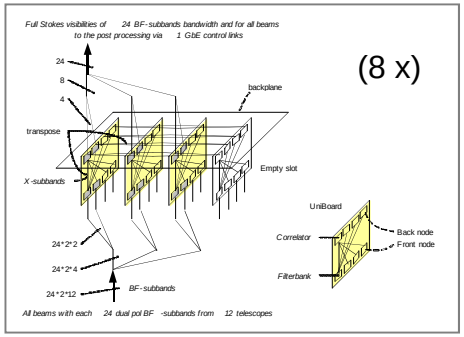
- **Combination of UniBoards into larger systems via backplane**

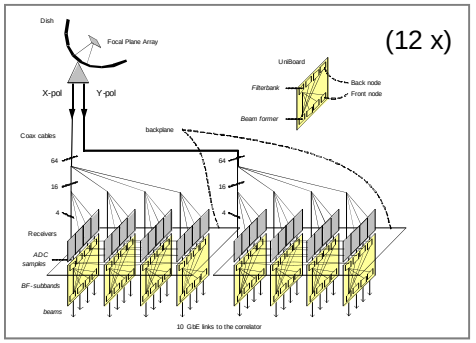
- Will be developed through NWO-funded ExBox project

- Application in APERTIF (ASTRON)
  - Correlator for 12 dual pol dishes, 300 MHz bandwidth, 37 beams

- Application in AARTFAAC (University of Amsterdam-ASTRON collaboration)
  - Correlator for 576 signal paths, ~ 17.5 MHz bandwidth



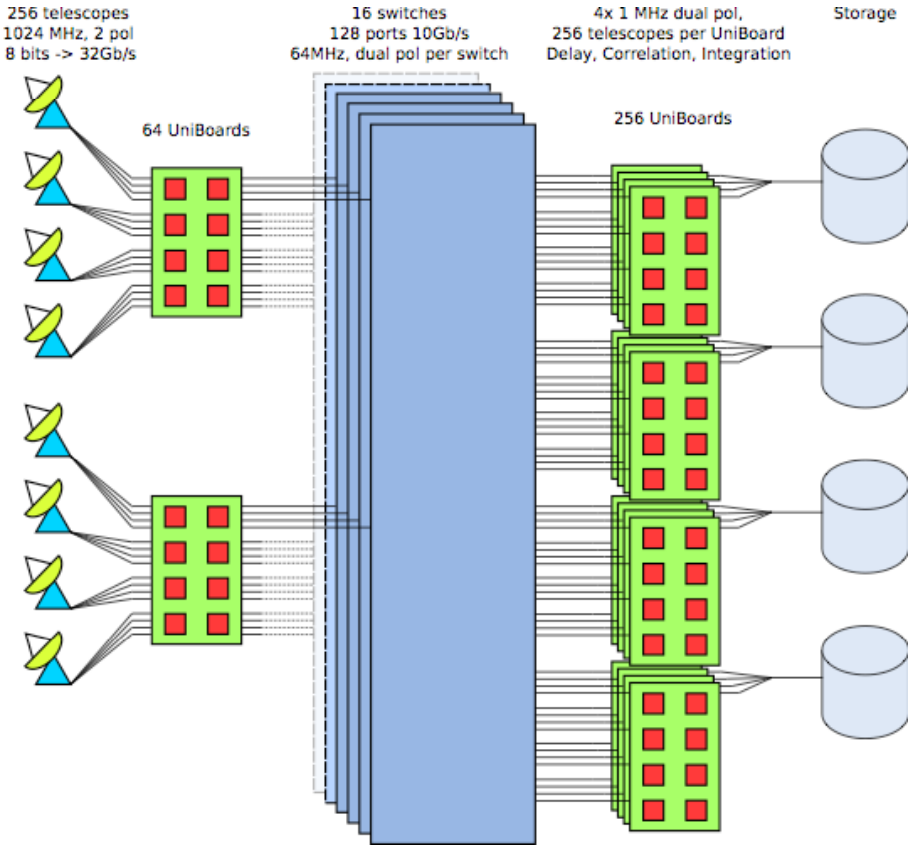




SKA mid-frequency correlator (1)

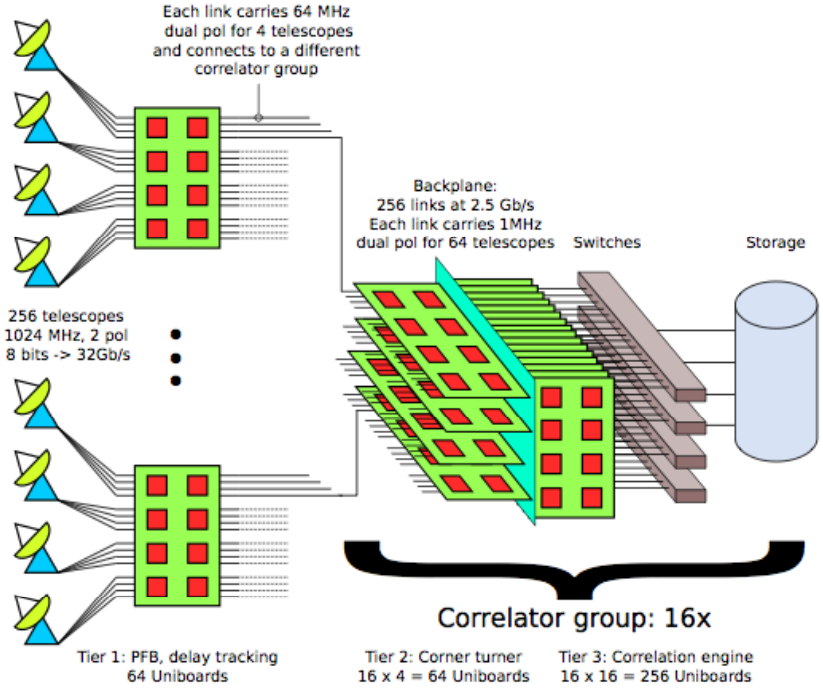
Mid-frequency:

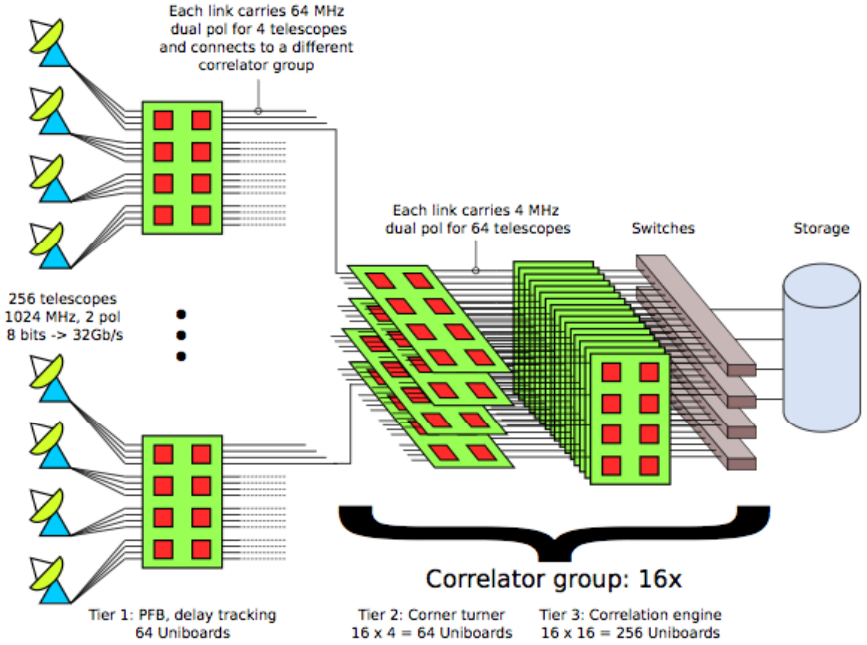
- 256 telescopes
- single pixel feeds
- 1024 MHz instantaneous bandwidth
- 2 pols
- 8 bits representation
- 7.5 kHz maximum resolution
- 0.1 s minimum dump time



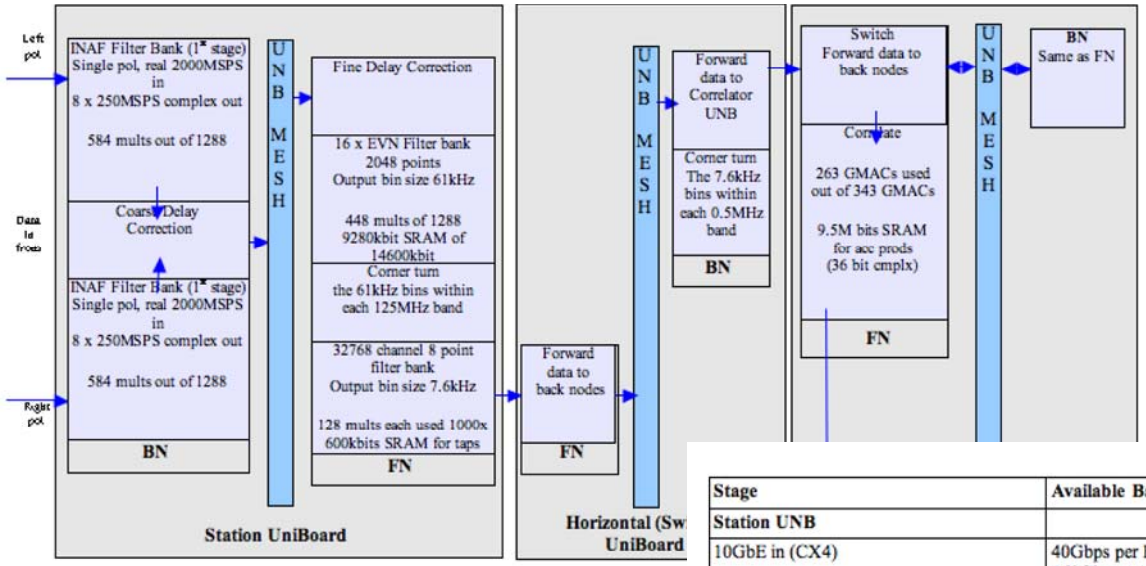
SKA mid-frequency correlator (2)

- Make use of excellent switching capability of UniBoard





SKA mid-frequency correlator (3)



- 384 boards
- ~170 kW
- ~3.8 Meuro

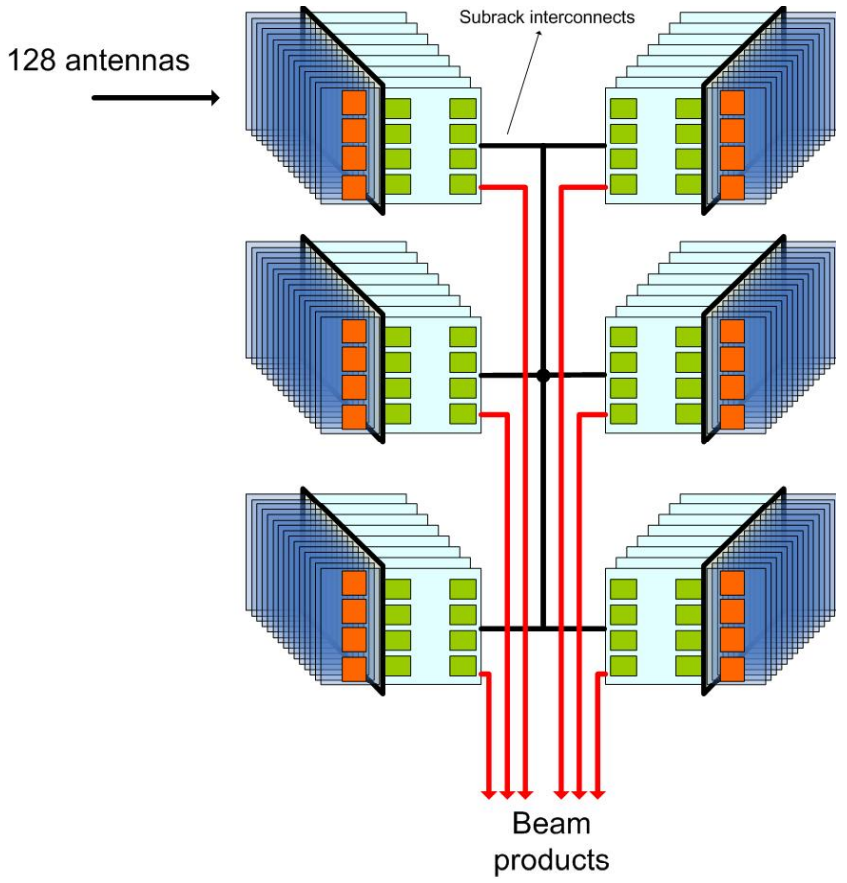
- Feasible…

Stage	Available Bandwidth	Needed Bandwidth
Station UNB		
10GbE in (CX4)	40Gbps per BN 160Gbps per UNB	32Gbps per BN, 128Gbps per UNB
Or LVDS in	32 LVDS pairs per BN	32 bits @ 512MHz DDR per BN
DDR3 coarse delay (BN)	68Gbps per DDR3 module	32Gbps read and 32Gbps write for 8 bit data
Mesh (BN->FN)	26Gbps per BN-FN pair	8Gbps for 8 bit data, 18Gbps for 18 bit data
DDR3 corner turning (FN)	68Gbps per DDR3 module	32Gbps read and 32Gbps write for 8 bit data
10GbE out (SFP+)	160Gbps per UNB	128Gbps per UNB
Horizontal (Switch) UNB		
10GbE in (SFP+)	160Gbps per UNB	128Gbps per UNB
Mesh (FN->BN)	26Gbps per BN-FN pair	8Gbps for 8 bit data
DDR3 corner turning (FN)	68Gbps per DDR3 module	32Gbps read and 32Gbps write for 8 bit data
10GbE out (SFP+ .. ?)	160Gbps per UNB	147Gbps per UNB
Vertical (Correlation) UNB		
10GbE in (SFP+)	160Gbps per UNB	9.2Gbps per FN, 37Gbps per UNB
Mesh (FN->BN)	26Gbps per FN-BN pair	2.3Gbps (including data hopped back to the FNs)
Mesh(BN->FN)	26Gbps per BN-FN pair	Need 1.15Gbps (the hopped data)
10GbE product out	20Gbps per FPGA, 160Gbps per UNB	0.1s integration time, 7.6kHz freq bin, 32 bit complex output: 5.3Gbps per FPGA, 42.7Gbps per UNB 4.1s integration time, 7.6kHz freq bin, 32 bit complex output : 0.13Gbps per FPGA, 1.0Gbps per UNB

SKA low-frequency beam former

Low-frequency:

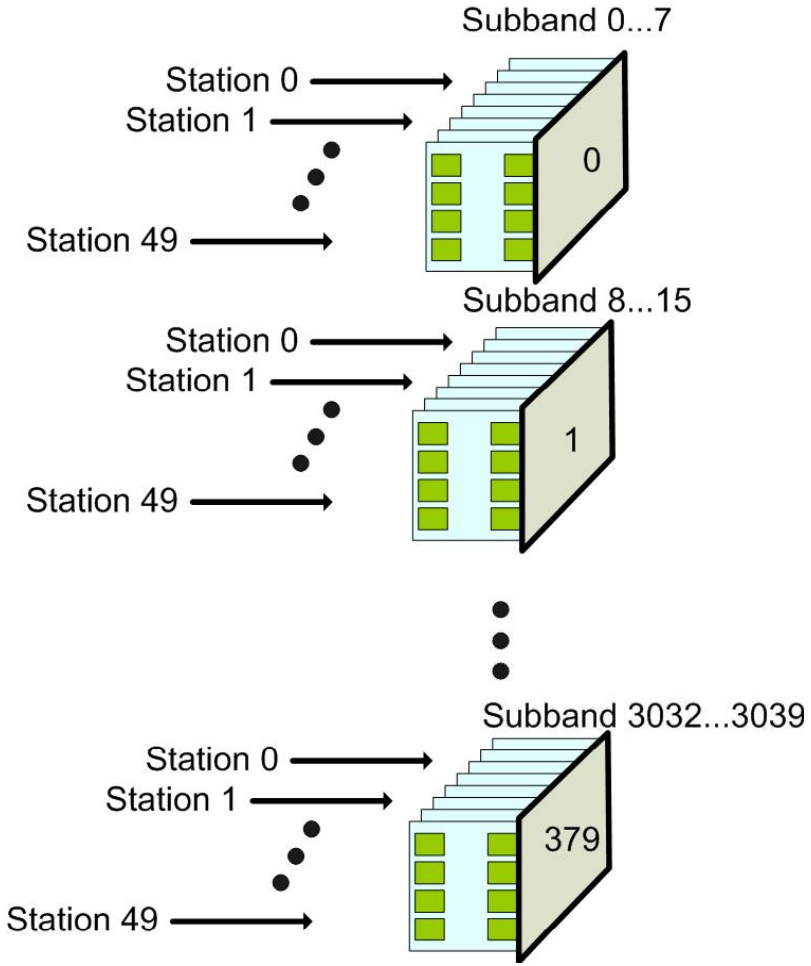
- Number of stations: 50
- Number of polarisations: 2
- Number of antennas / station: 11200
- Input bandwidth: 500 MHz
- Output bandwidth: 380 MHz
- Number of beams: 160
- Number of input bits from the station ADC: 8
- Number of output bits to the correlator: 4 x 2
- Subband width: 125 kHz
- Channel width: 1 kHz



SKA low-frequency correlator

- 50 stations, 160 beams
- (correlation + beam forming)
- 9414 boards
- 90 Meuro
- 3.3 Mwatt

- But, *currently* available hardware
- ~2 generations of FPGA until 2015



Next: UniBoard^2

- Possible Joint Research Activity in RadioNet3, follow-up of current project, start date 2012 (if approved by EC) (looking good)
- Received strong support from RadioNet community
- Same basic idea, development of generic hardware complemented by a number of applications
- Consolidate and build on expertise obtained through UniBoard project
- **Strong emphasis on power efficiency (green computing)**
- Production-ready in 2015/2016

- **Complete re-design, using the next generation 28 nm FPGAs**, possibly one generation beyond that (some slack in start date of project)
- **Non-leaded components**
- Possible use of **40GE, 100GE**
- Investigation into effects of **hard-copy** and **partial hard-copy**
- **Tuning of algorithms and firmware design** to minimize power consumption
- **Balancing of system parameters and performance** to minimize power consumption
- **Standardized interfaces and coding conventions** to facilitate sharing and re-use of firmware blocks among developers of different applications