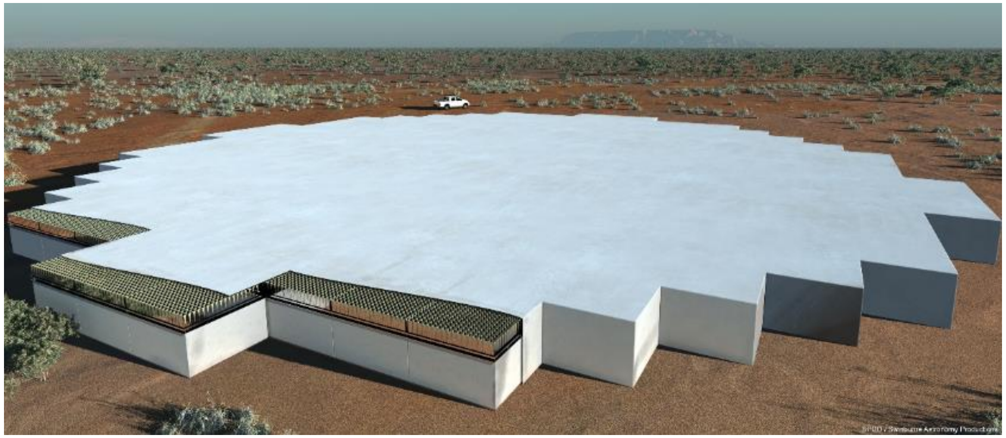
The AAMID consortium:

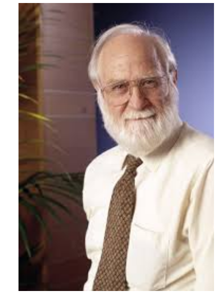
Mid Frequency Aperture Array

Wim van Cappellen, Consortium Lead



ASTRON · Station de Radioastronomie de Nançay · Manchester 1824 The University of Manchester · université de Bordeaux · University of Cambridge · KLAASA · Universiteit Stellenbosch University

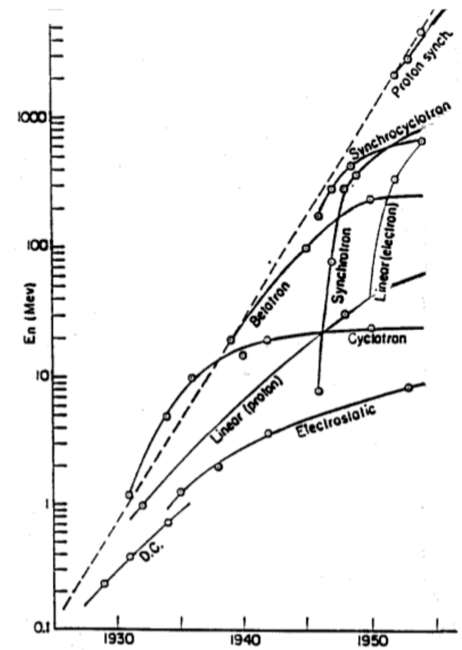
Livingstone curves



- Brought to our attention by Ron Ekers

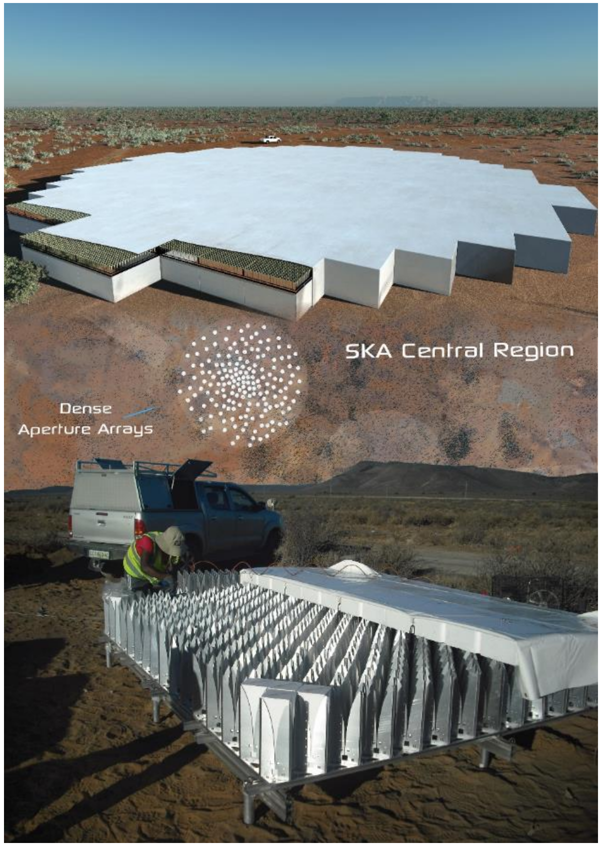
- Technological capability leads to discovery in astronomy
- A single technology saturates in capability
- Innovation is needed to continue exponential growth

- Review committees are risk averse and have a tendency to stick to traditional technologies.
- Adopting new technology leads to great rewards



MFAA has

- A very large field of view, and the opportunity of transient buffering
- A fast response time and pointing
- Multiple beams, concurrent observations
- A very high survey speed capability
- High sensitivity < 1.4 GHz
- Relatively low capital and operational costs
  - Low post-processing costs (large stations)
  - No moving parts
  - No vacuum, helium, cryogenics



$$P_{imager} = N_{op} \underbrace{\frac{10^5}{3} \frac{T_{obs} N_{stat}^2}{f_{min}} \frac{B_{max}^2}{D_{stat}^2}}_{\text{number of visibilities}} \left(\frac{\lambda_{max}^2 B_{max}^2}{D_{stat}^4} + N_{kernel}^2 \right)$$

MFAA will drive science discoveries

- Transients
  - J.P. Macquart: “There is no substitute for Field of View,
    twice the beams = twice the science”.
  - FRB’s, RRAT’s, and many others.
- Pulsars
  - Bulk pulsar timing, high cadence long-term timing, vast improvement of on-source time, surveys
- HI
  - Deep survey, fast wide survey, regular re-observation
  - Local HI, Billion Galaxy Survey, Intensity Mapping
- Cosmic Magnetism

Outline

- AAMID Consortium Overview
- Towards SKA2-MFAA
- Schedule
- Highlights of AAMID activities
- Summary

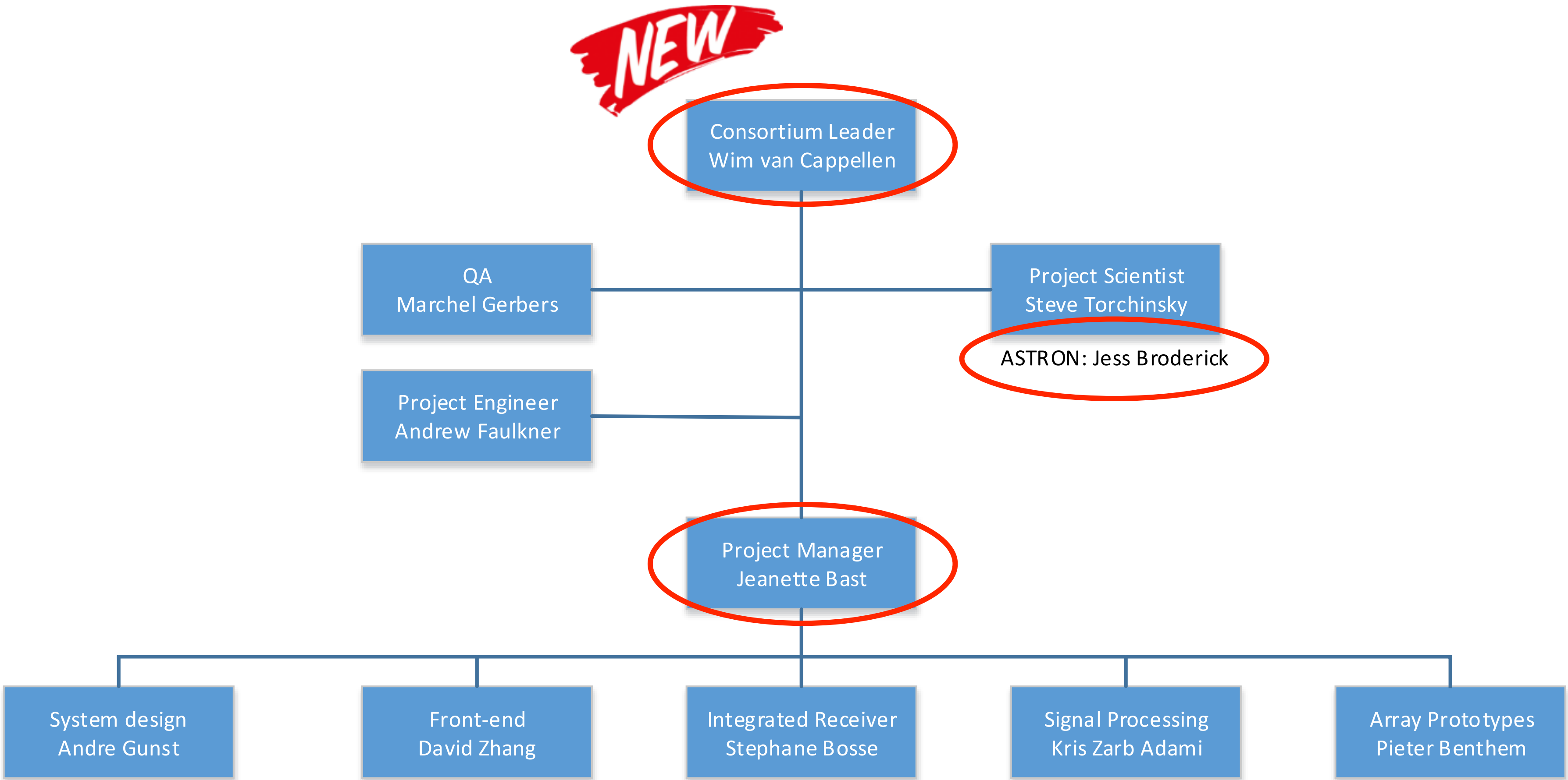
The AAMID Consortium

- It is projected that an AAMID full telescope can be built for less than 1 B€ starting in 2025.
  - Sensitivity 10,000 m^2/K
  - 100+ sq degrees Field of View

- The AAMID consortium aims to demonstrate maturity, competitiveness and cost-effectiveness of Mid-Frequency Aperture Arrays for SKA2.

- SKA Advanced Instrumentation Programme (AIP)
  - Innovative technology development

Consortium Organization



Consortium partners

Full members

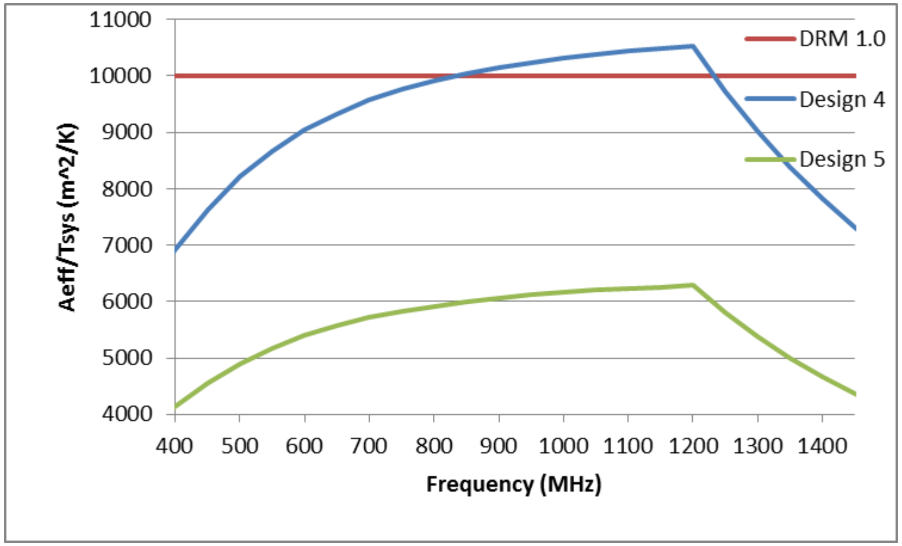
– ASTRON	*System design, prototyping, management*
– China: KLAASA	*Receiver, antenna: 3x3 m^2 array*
– Observatoire de Paris (Nancay)	*Front-end MMIC's*
– Stellenbosch University	*Antenna research*
– University of Bordeaux	*ADC*
– University of Cambridge	*System design*
– University of Manchester	*Front-end design*

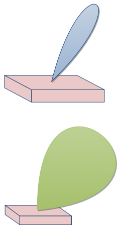
Associate members

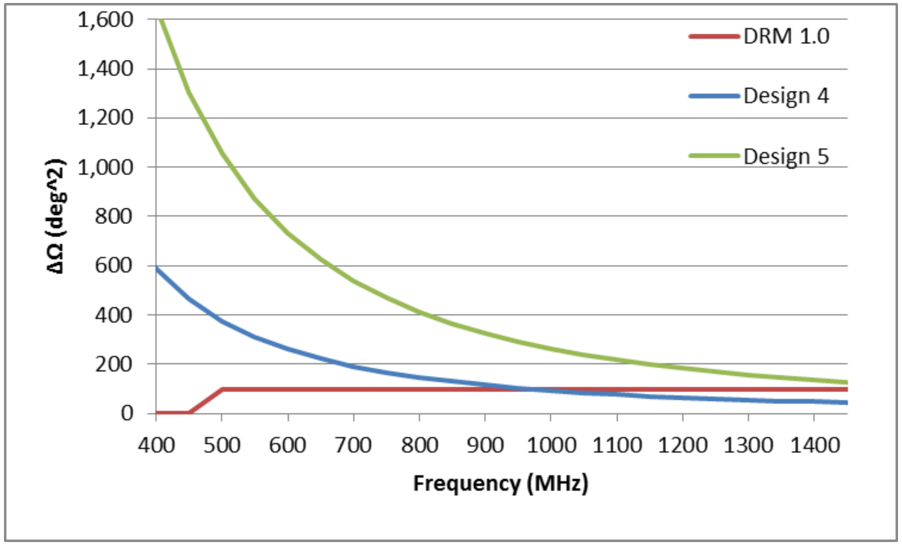
– ENGAGE SKA (Portugal)	*Renewable energy*
– SKA South Africa	*Site support*
– University of Malta	*Fractal ORA*
– University of Mauritius	*Front-end research*

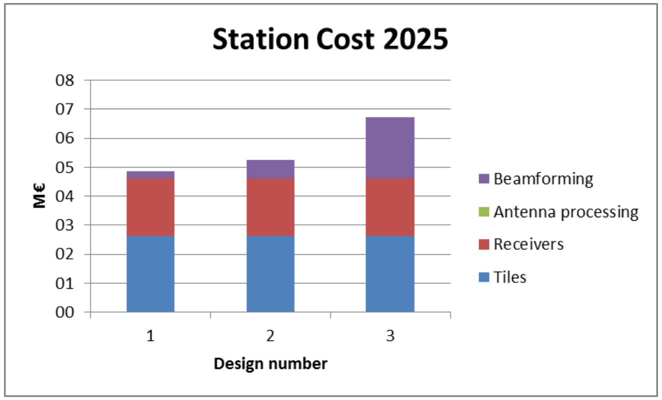
System Design

- Tailoring the design to optimally cover L0 requirements
- Several designs are traded-off
- SRR in April 2016









SKA2-MFAA

- An AAMID full telescope can be built for less than 1 B€ starting in 2025.

- More detailed modeling ongoing in collaboration with the ASTRON & IBM Center for Exascale technology (DOME)

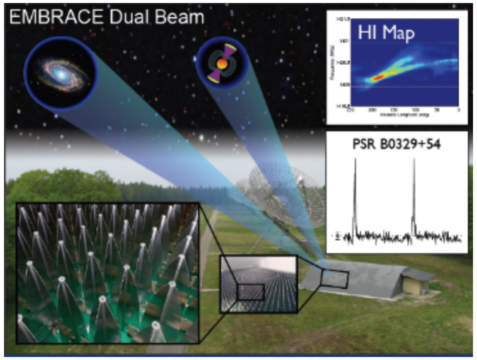
Item		Deployment Costs
1	AA stations (MFAA)	€550M
2	Infrastructure	€75M
3	Correlator	€50M
4	Image data processing	€240M
5	Data transport	€15M
6	Telescope manager	€10M
7	AIV	€5M
		€945M

Source: MFAA system team

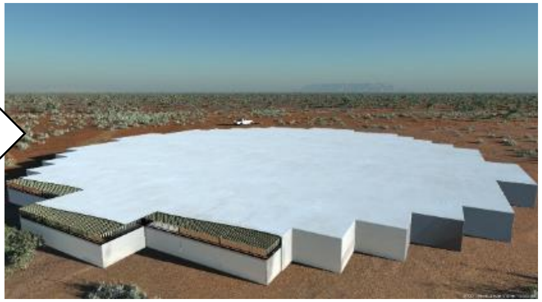
Key challenges

- Reducing the front-end capital costs
- Reducing of operating costs / power consumption
- Imaging dynamic range: Calibration down to thermal noise needs accurate beam and sky models to calibrate sources in near and far sidelobes

The way forward



Science capable demonstrator



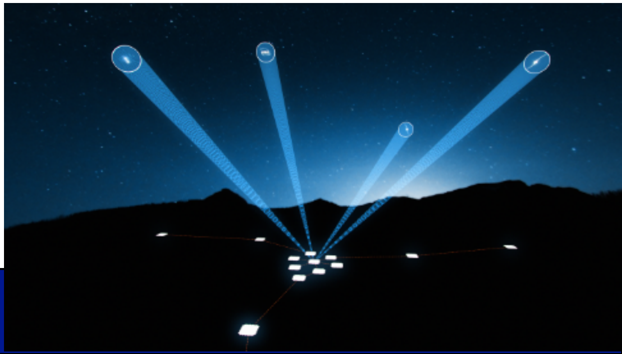
Demonstrator

- Located on the South African SKA site
- Demonstrate feasibility and technological maturity
  - Technical verification
  - Science observations

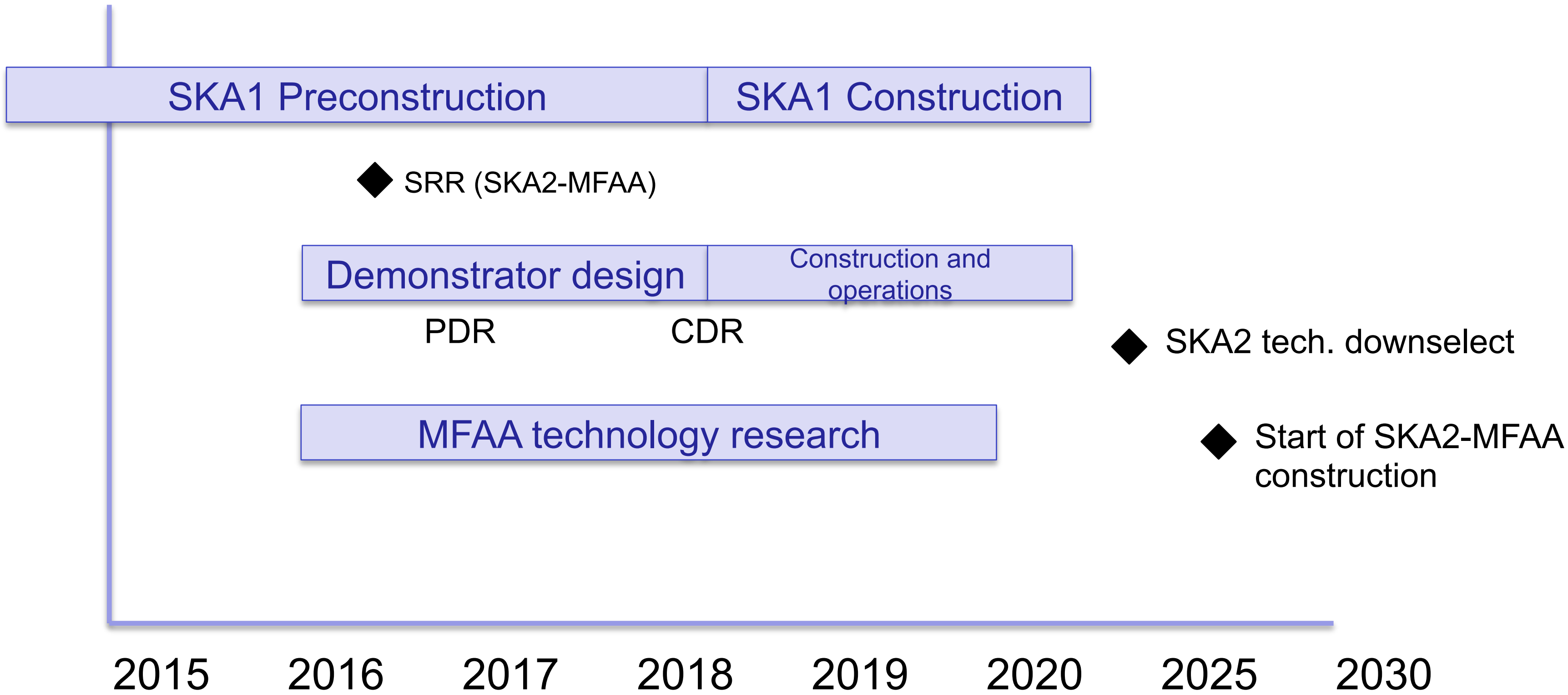
Possible demonstrator specs

Parameter	Value or range	Units
A_{eff}/T_{sys} at 1GHz	40	m^2/K
Frequency range	500 - 1500	MHz
Bandwidth	>500	MHz
Baseline length	300 - 1000	m
Compactness	50%	A_{eff} inside 100m
Number of stations	10 - 20	
Independent fields-of-view	≥2	
HPBW (FoV) at 1GHz	15 (175)	deg (deg^2)
Polarizations	Full Stokes	

- A_e ~2000 m^2



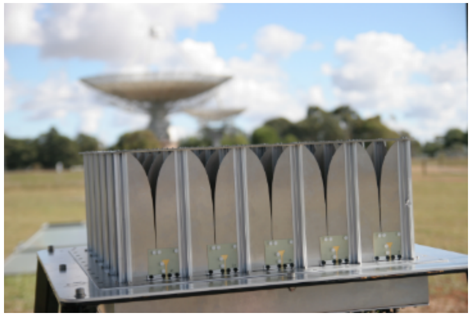
MFAA Overall planning

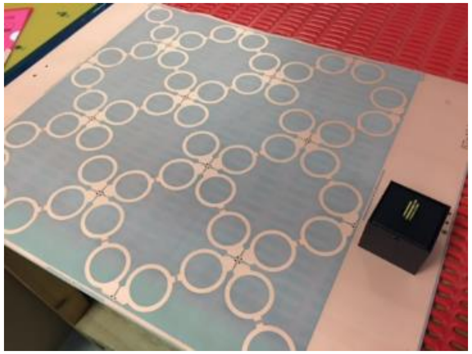


Consortium Activities

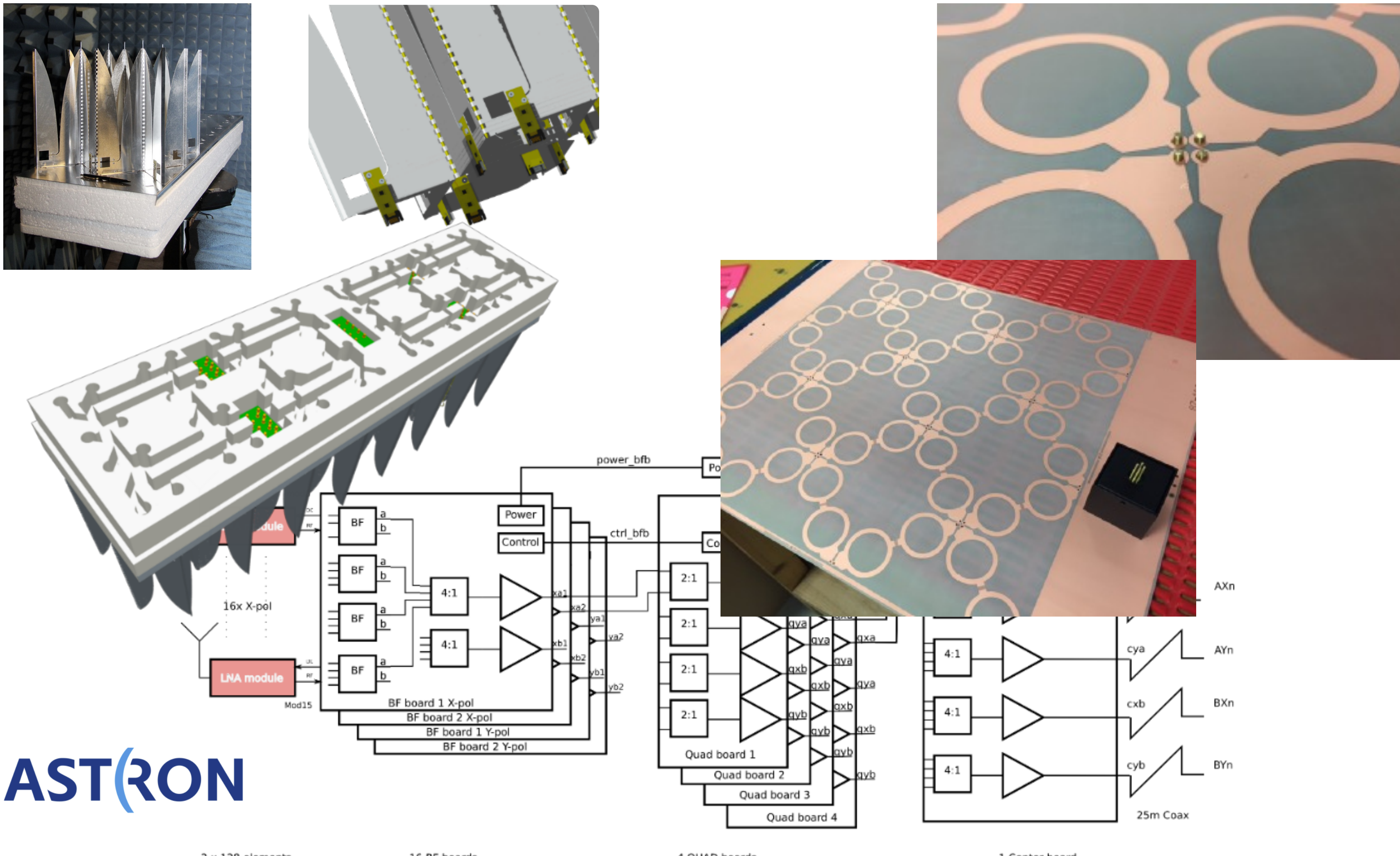
- Focus on Front-end development
  - Cost
  - Power consumption
  - Dense and sparse arrays
  - Environmental testing

- Performance and cost modeling of the entire SKA2-MFAA **telescope**

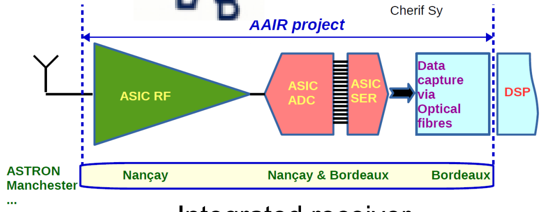




Front-end development

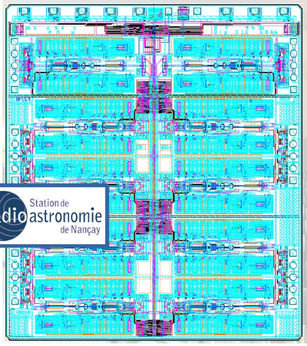


Front-end development



Integrated receiver

BeamFormer with TimeDelay



X = 3.190 mm with sawlane
Y = 3.594 mm with sawlane

Surface = 11.5 mm2

Current < 220 mA

Power supply = 3.3 V

Power consumption ≈ 720 mW

Frequency Band = [0.5 – 1.5 GHz]

Process Qubic4Xi NXP version 9.4

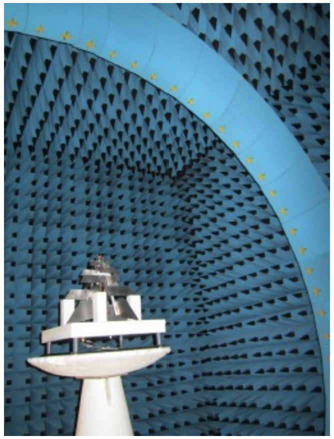
Differential Beamformer
4 channels 2 Beams

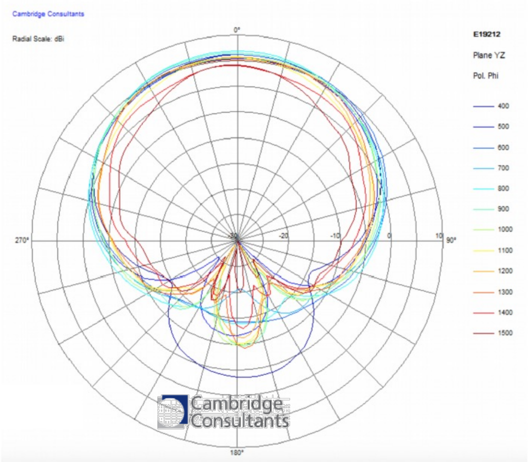
Delay = 1200 ps *2 , step = 20 ps

VGA = 6 dB 4 bits

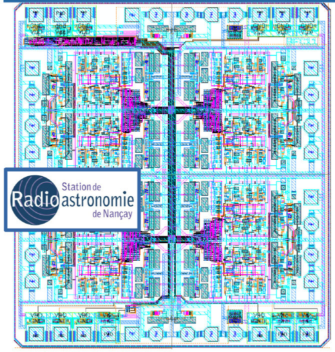
Differential Input imp. matching = 150 ohms
Differential Output imp. matching = 150 ohms

Digital control : I2C or SPI





Beamformer with Phaseshifting



X = 1.622 mm with sawlane
Y = 1.772 mm with sawlane

Surface = 2.9 mm2

Current < 150 mA

Power supply = 3.3 V

Power consumption < 500 mW

Process Qubic4X NXP version 9.0

Differential Beamformer
4 channels 2
Beams
PhaseShifting = 360 ° 4 bits (step = 22.5 °)

VGA = 4.5 dB 3 bits

Differential Input impedance matching = 200 or 150 ohms
Differential Output impednce matching = 200 or 150 ohms

Digital control : I2C or SPI, supply = 3.3 V

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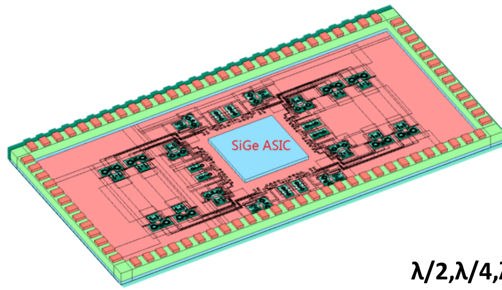
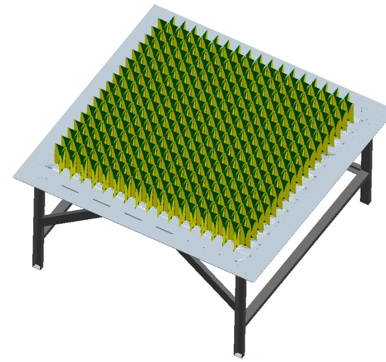
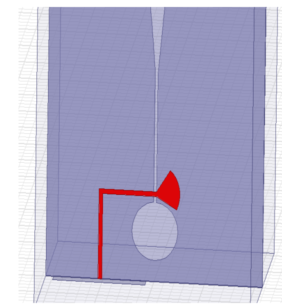
Front-end development

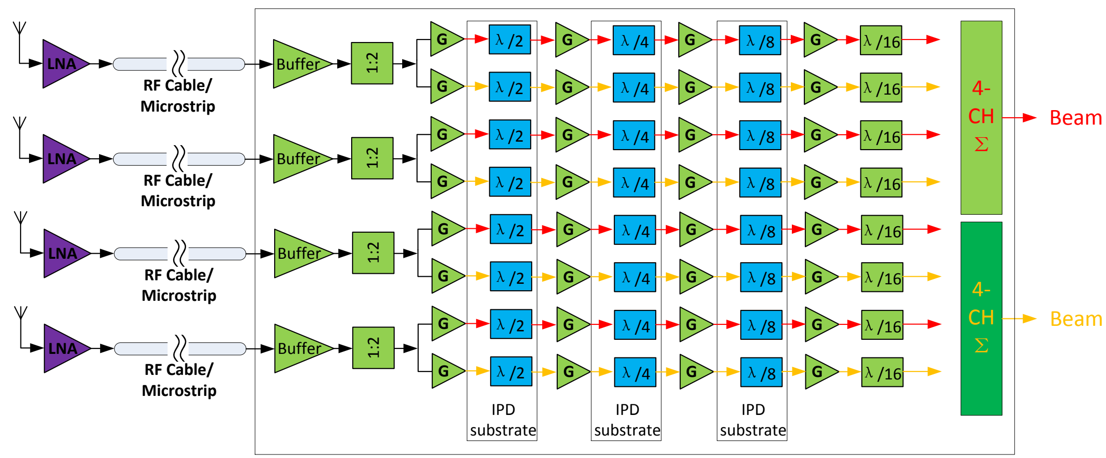
- 16x16 Vivaldi antenna tiles







λ/2,λ/4,λ/8 are lumped delay lines integrated on IPD substrate

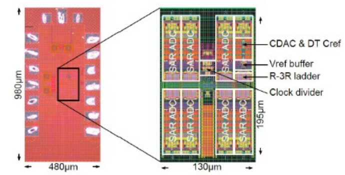


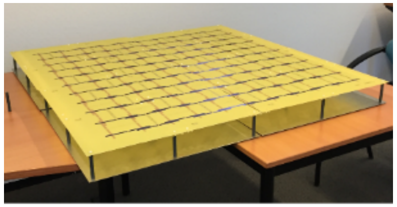
GaAs LNA

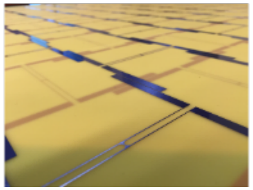
Beamformer SiP Module (SiGe chip + IPD substrate)

MFAA related technology research

- ASIC development for receiver and digital beamformer
- Photonics RFoF
- Alternative antenna types
- New production methods
  - 3D MID
  - 3D Printing
- Durable solutions
  - Bioplastics, biofoams (radome)
  - Energy



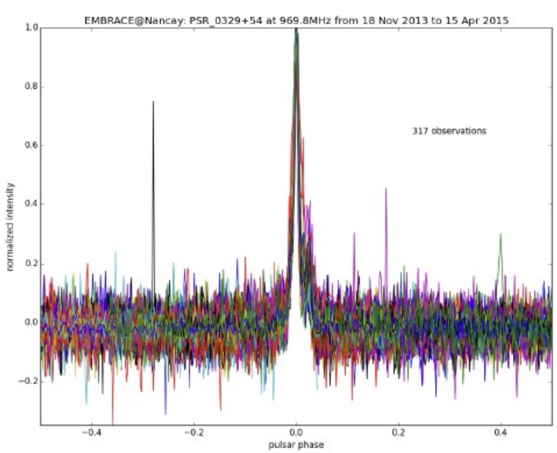


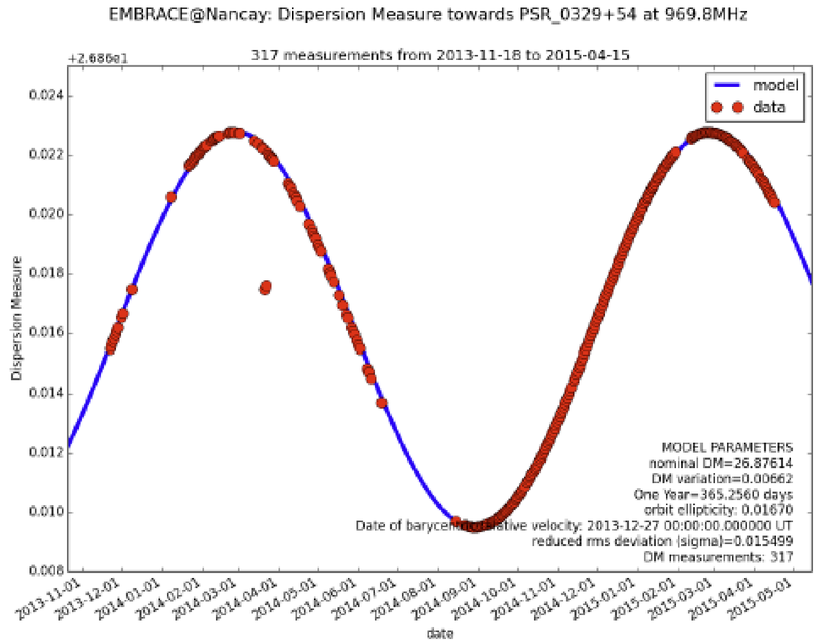


EMBRACE: DM Seasonal Variation

Station de Radioastronomie de Nançay

- Pulsar monitoring
- B0329+54 at 970 MHz
- 317 pulse profile measurements between 18 Nov 2013 and 15 April 2015
- Tests stability and reliability of the system





The Earth goes around the sun in one year!

S.A. Torchinsky et al., http://arxiv.org/abs/1504.03854

Solar Eclipse observed with EMBRACE

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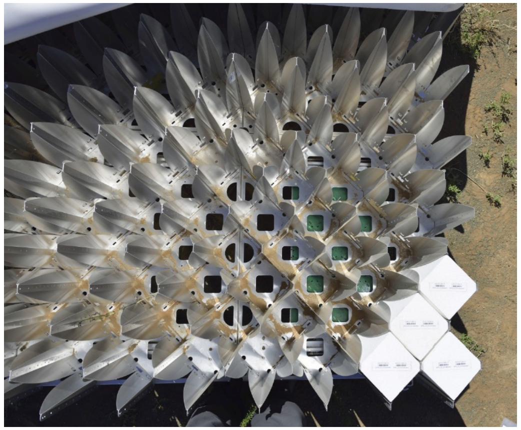
Environmental prototypes

- Environmental proto-types in the Karoo, South Africa
- Goal: Identify the “fuzzy” environmental design drivers
  - Dust, soil variation, erosion, vegetation, bugs, rodents, wildlife, birds, water, puddles, floods

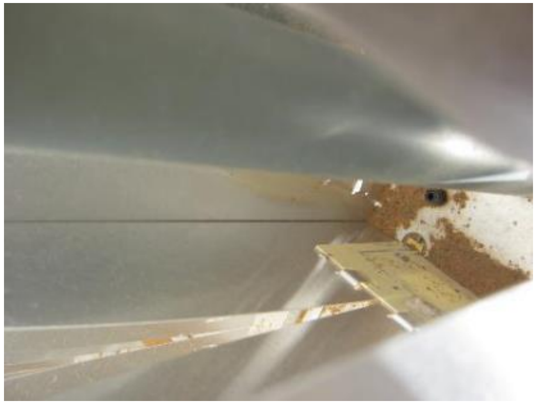
Current status



Dust collection

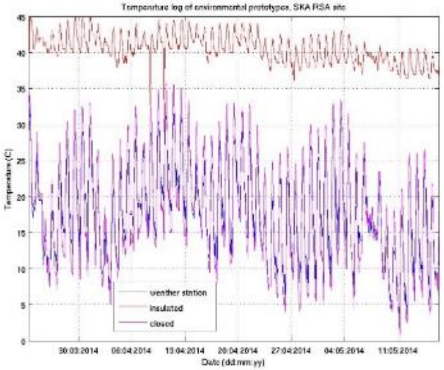
Dust and pooling of water

Wire failed



Dust collection

UV impact on PP



Temp logging

For your agenda:

- MIDPREP / SKA AA-MID

  Science and Engineering Workshop

- 7 – 9 March 2016
- Cape Town, South Africa

Summary

- We should be courageous! Investment in new technology is essential for the continuation of discoveries in science
- SKA2-MFAA optimally uses new technology to enable key SKA2 science
- System with 10,000 m^2/K and >100 sq degrees Field of View is projected at 1 B€ in 2025

- Working towards a science capable demonstrator

MFAA meeting this Friday, 13.30h, Zinfandel room