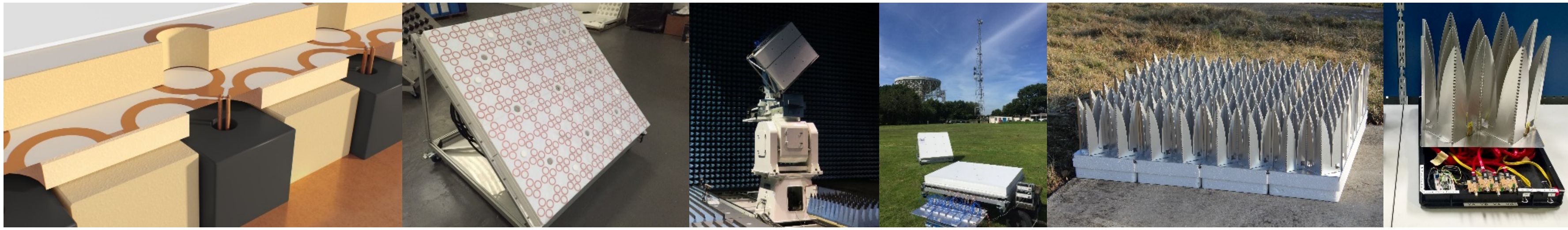

Front-End Design for Mid-Frequency Aperture Array

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Severin Barth, S. Bosse, S. R. Harison
Obs. de Paris, Nancay

Rui Cao
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ASTRON, the Netherlands

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University of Cambridge

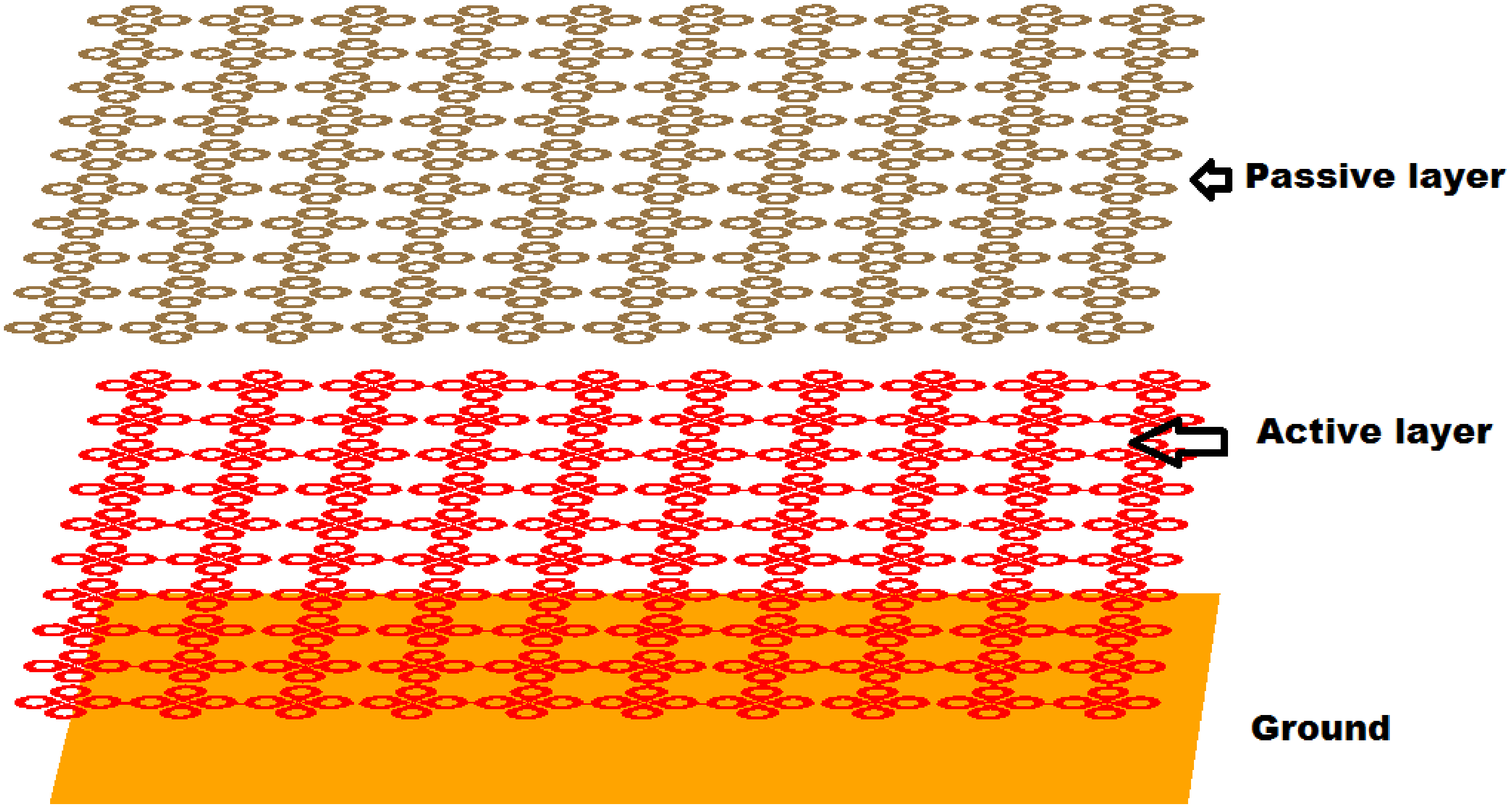
SKA AIP Meeting, ASTRON, 8-9 June, 2017

Outline

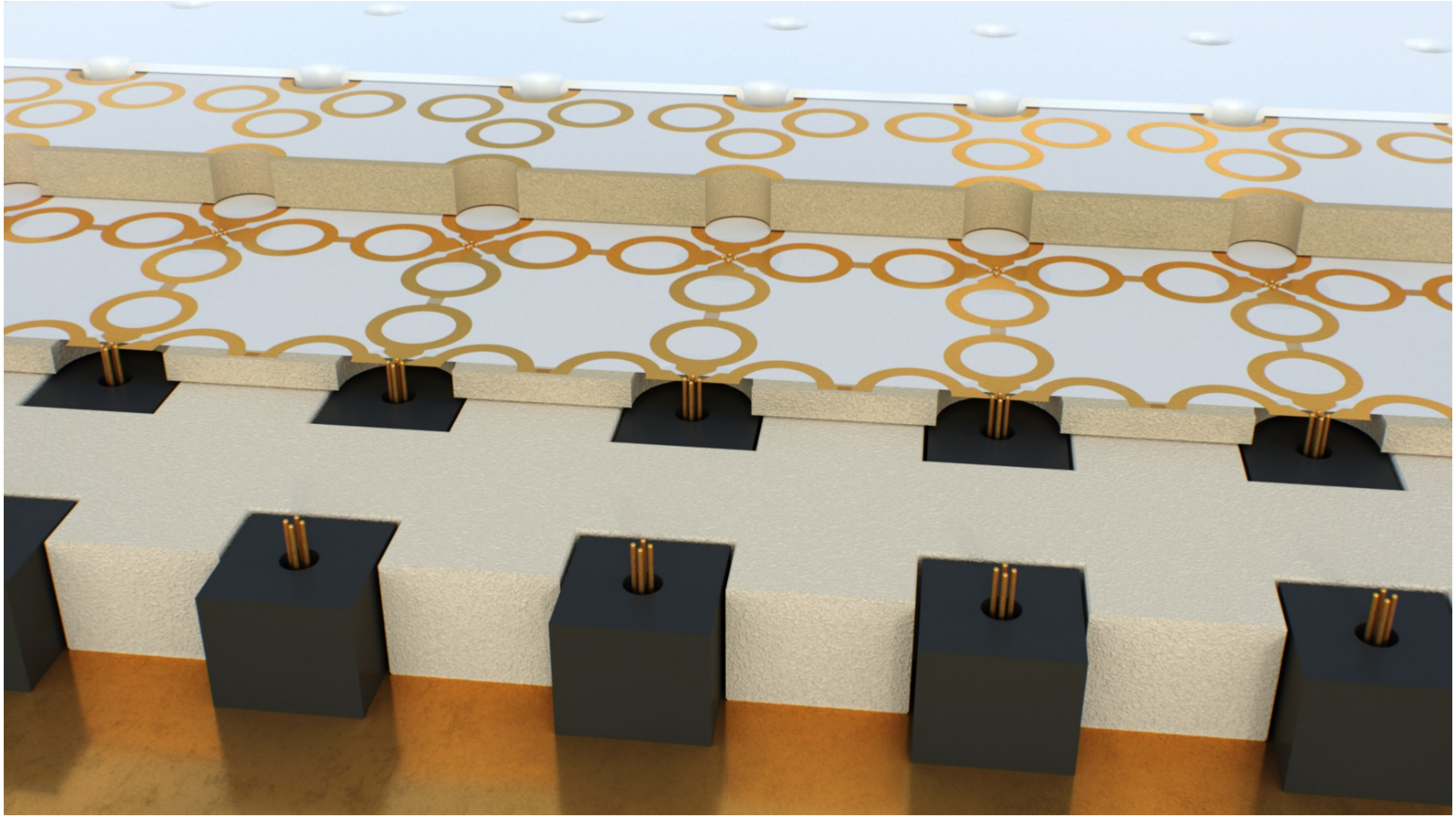
- Full Differential Front-End Development
  - Review of C-ORA (Crossed Octagonal Ring Antenna)
  - Prototype investigation
  - Active C-ORA array measurements
  - System integration with time delay based beamformer
- Single-Ended Front-End Development
  - ASTRON
    - Active Vivaldi Antenna Array
    - Integration with phase shifter based beamformer
  - KLAASA
    - Front-End solution and back-end processing
- Sparse Array Design for MFAA

Review of Crossed Octagonal Ring Antenna (C-ORA) Design

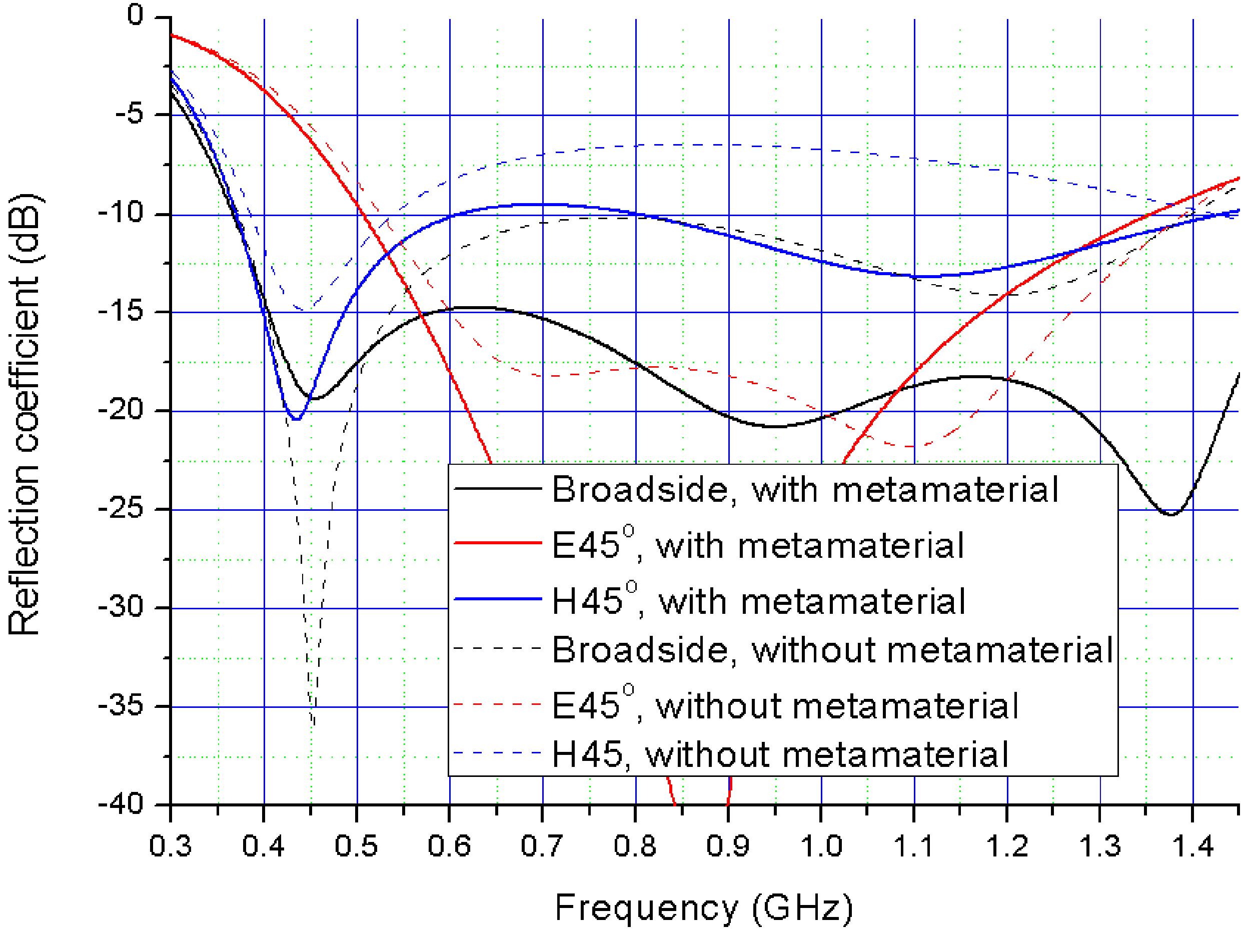
C-ORA Design



The Layered Structure



Metamaterial performance in C-ORA

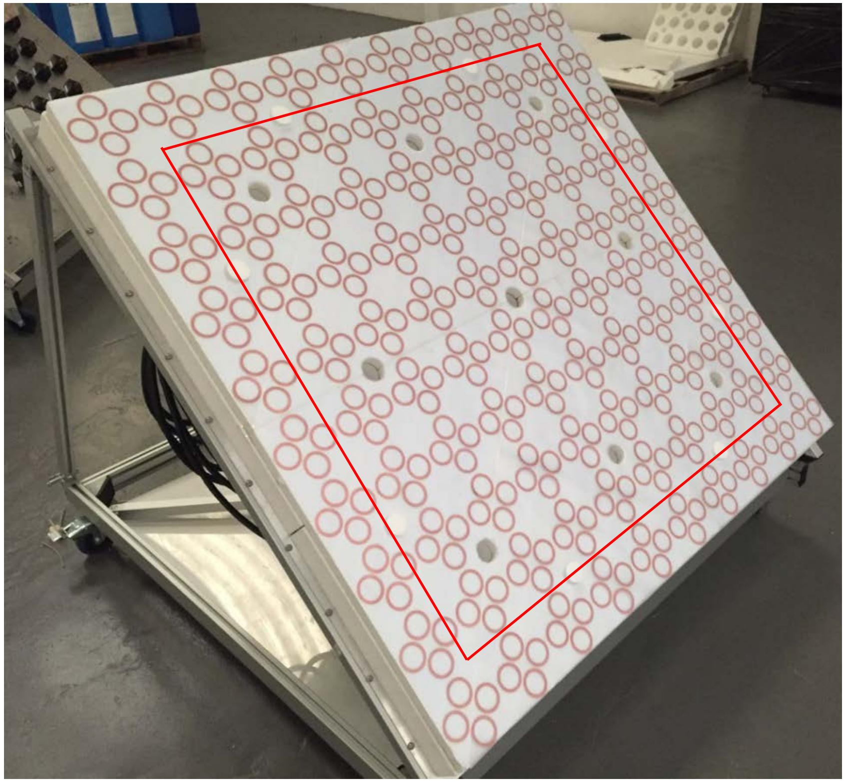


MID-FREQUENCY APERTURE ARRAY

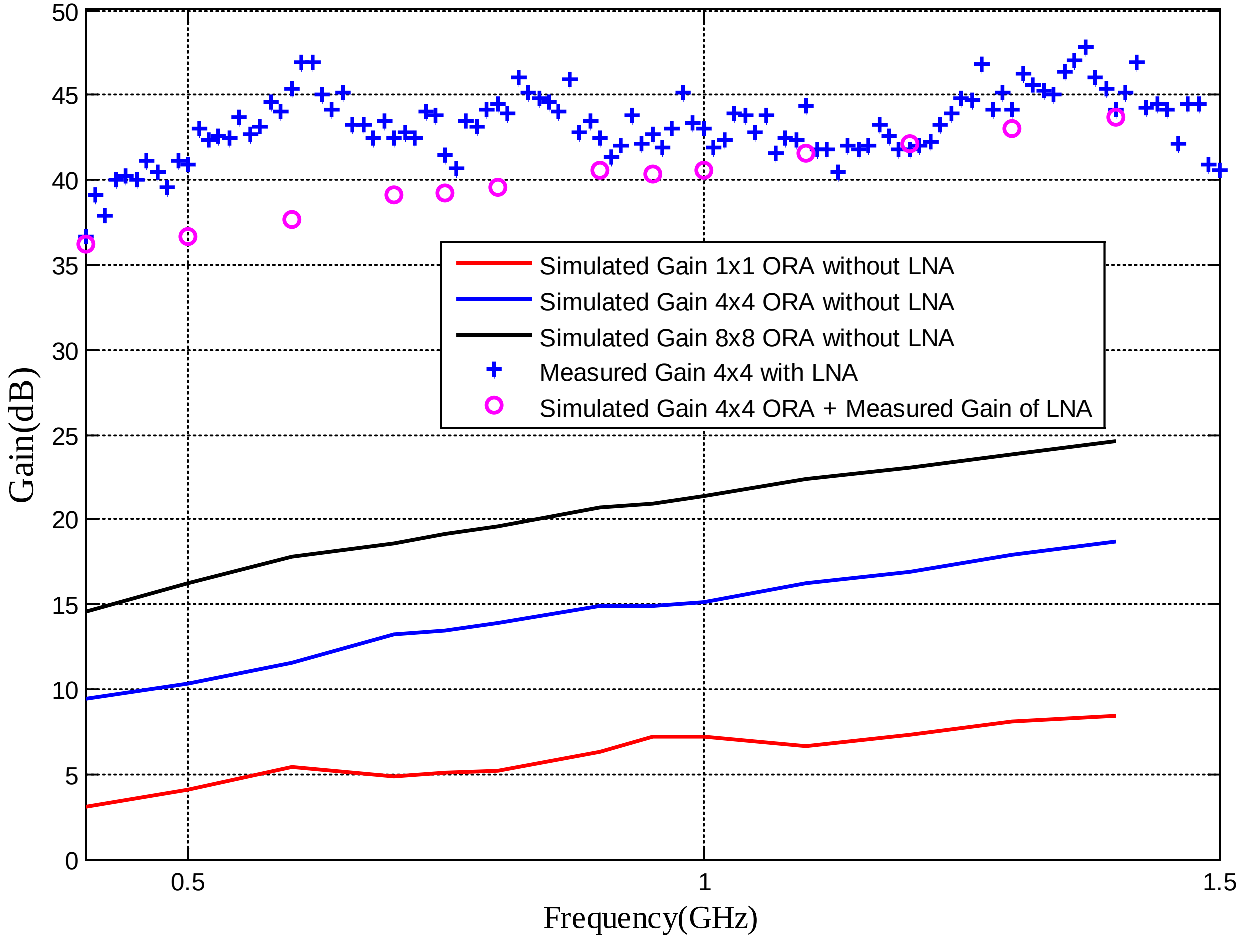
Prototyping and Active ORA Array Measurements

The 1 m^2 ORA prototype facts

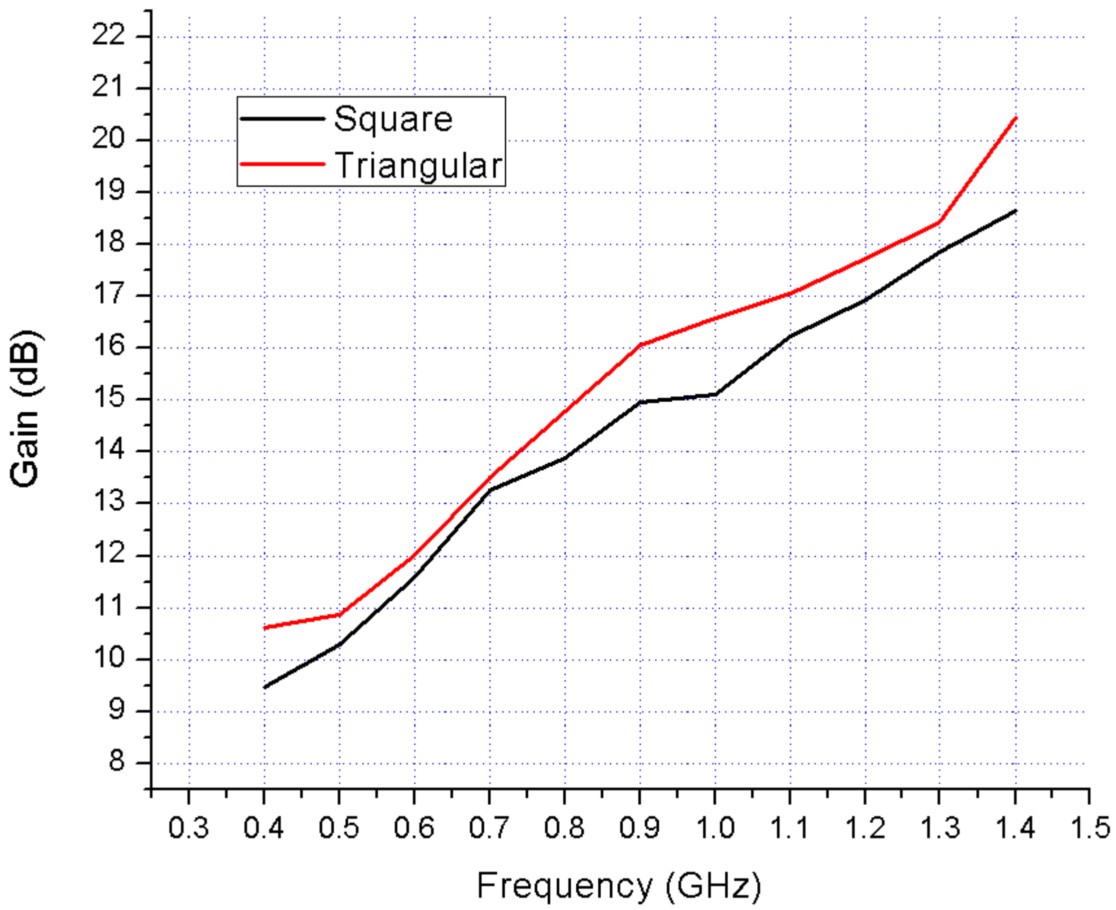
- 10x10 elements(1.25m x 1.25m)
- Dual-polarised for each element
- Frequency 400MHz to 1450MHz
- Element separation: 125mm
- Low profile (array thickness <10cm)
- 64 (8x8) central elements excited (within the red box)
- 36 edge elements terminated with the matched load
- 128 LNAs integrated (64 for each polarisation)



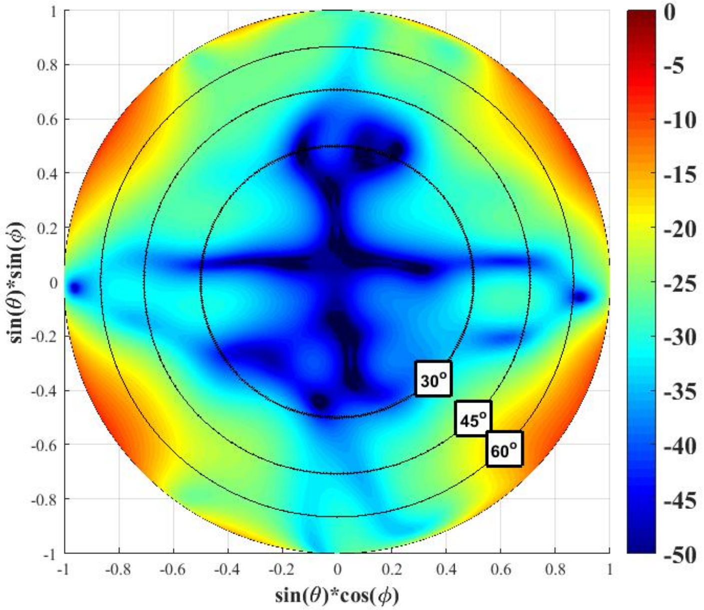
Gain measurements at field



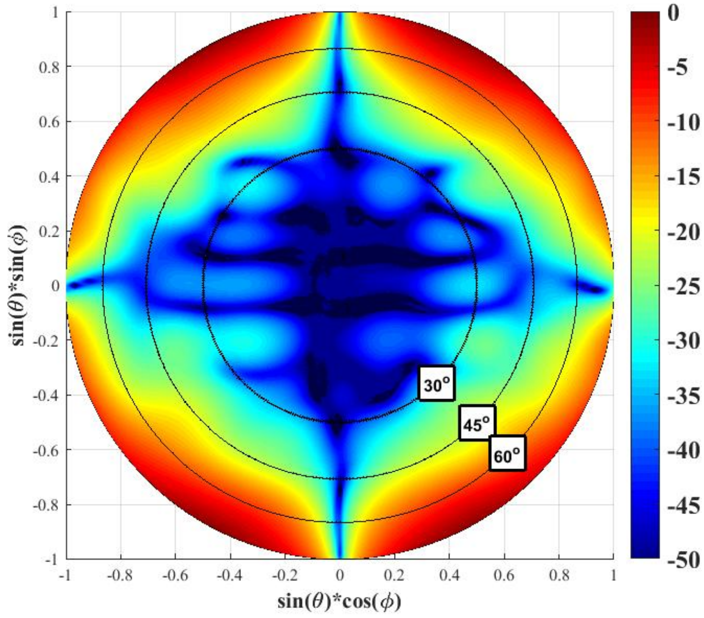
Gain comparison for 4x4 Arrays



Raw cross polarisation – XPD



900MHz



1200MHz

Calibration Error and IXR

$$\begin{pmatrix} f_p \\ f_q \end{pmatrix} = \begin{pmatrix} J_{px} & J_{py} \\ J_{qx} & J_{qy} \end{pmatrix} \begin{pmatrix} e_x \\ e_y \end{pmatrix}$$

Measured voltage → $f = Je$ ← Raw voltage

Intrinsic cross-polarization ratio

$$IXR = \left(\frac{\kappa(\mathbf{J})+1}{\kappa(\mathbf{J})-1} \right)^2$$

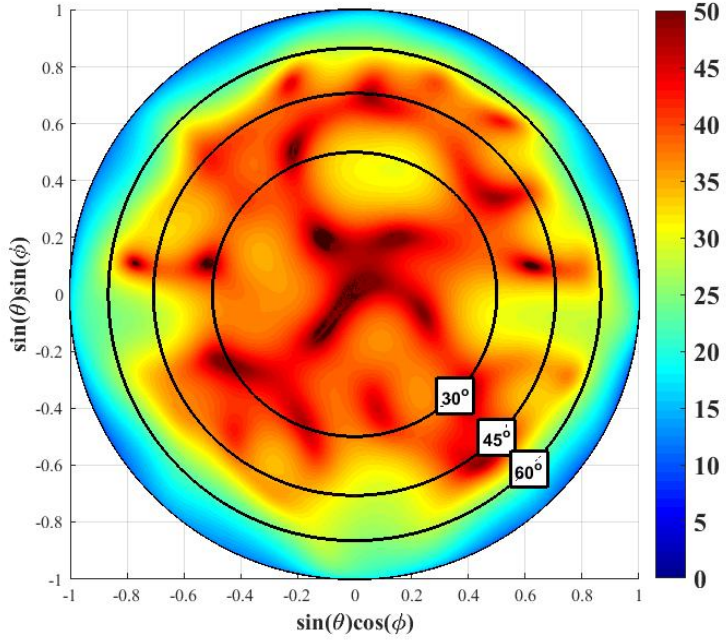
$$e = J^{-1} f$$

$$f + \Delta f = (J + \Delta J)(e + \Delta e)$$

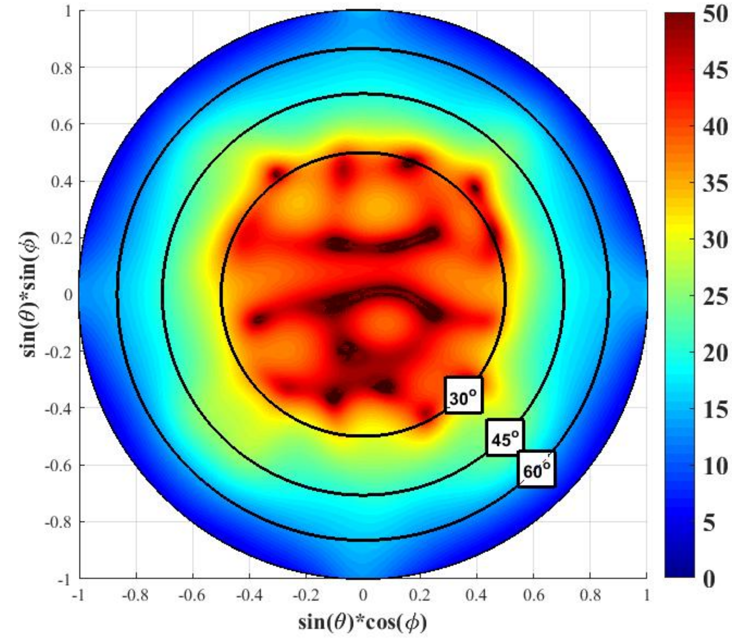
$$\left\| \frac{\Delta e}{e} \right\| \leq \left(1 + \frac{2}{\sqrt{IXR}} \right) \left(\left\| \frac{\Delta f}{f} \right\| + \left\| \frac{\Delta J}{J} \right\| \right)$$

An IXR of 25 dB limits the potential increase
in the relative Stokes error during reconstruction to 22%

The IXR (Intrinsic Cross-Polarisation)

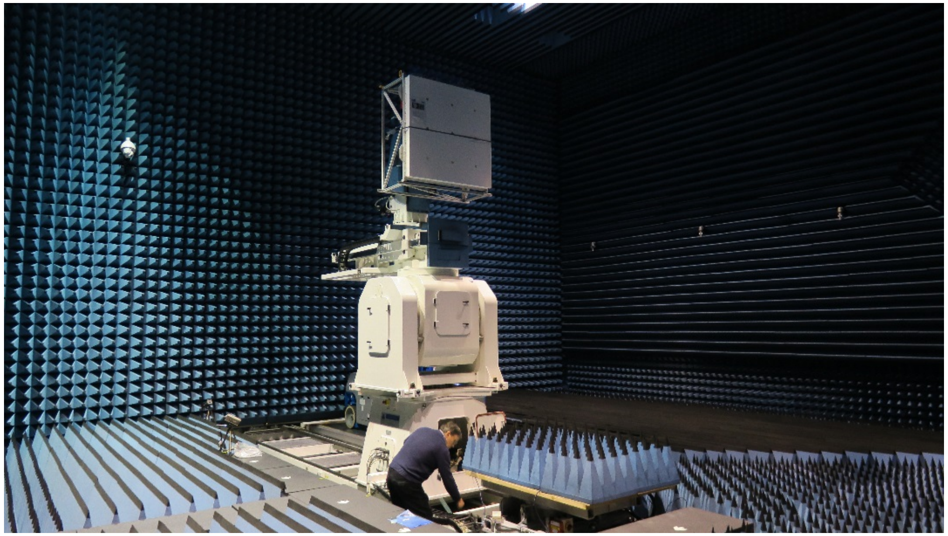


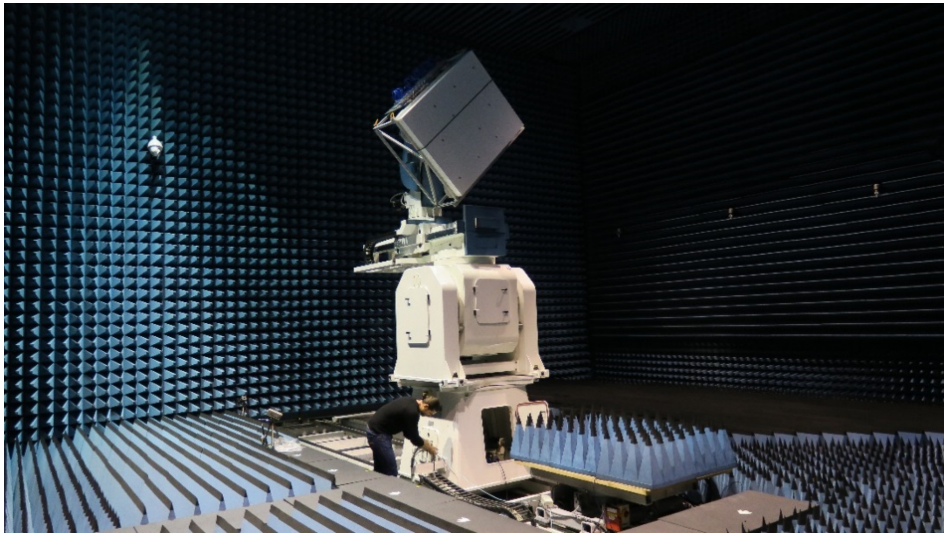
900MHz



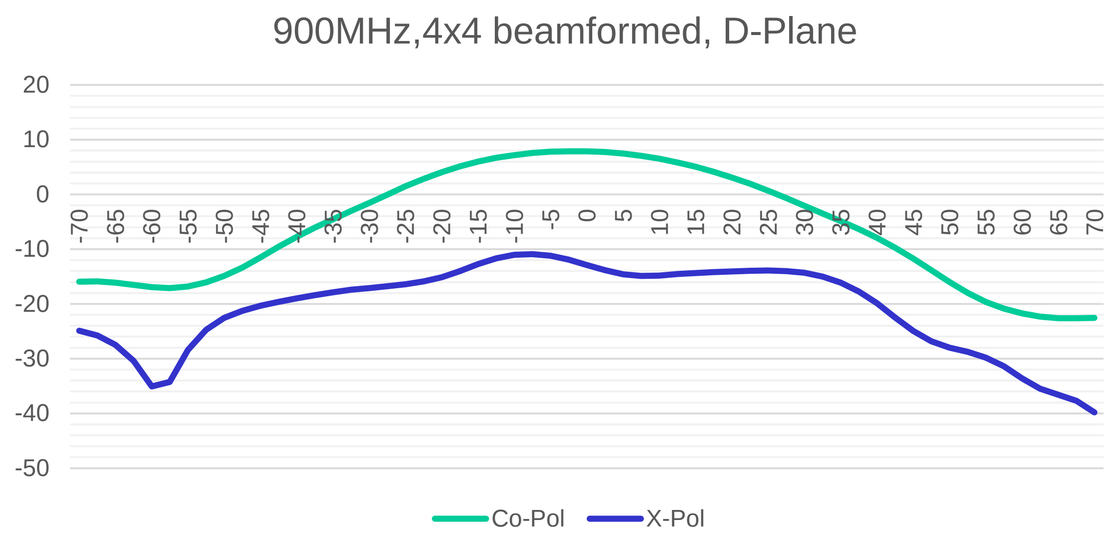
1200MHz

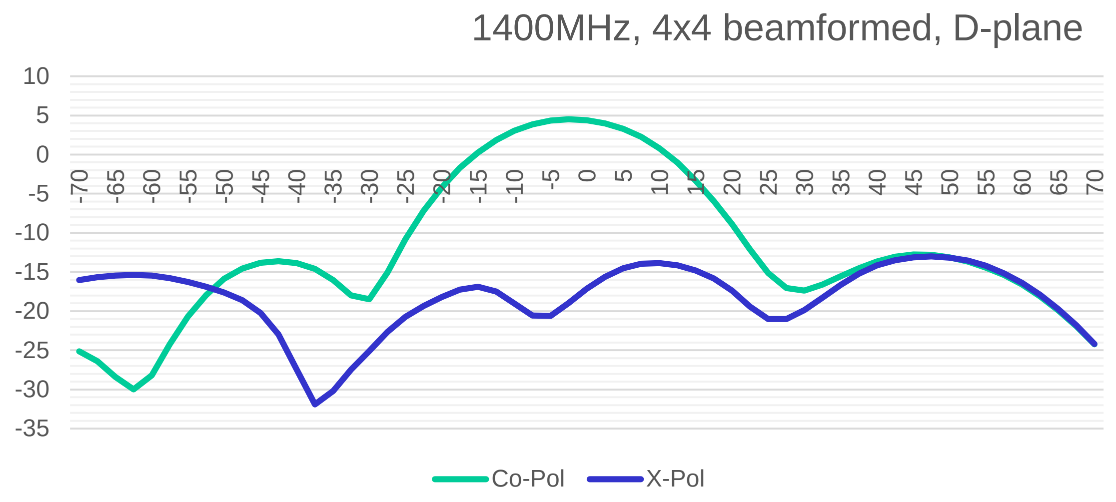
The radiation pattern measurement



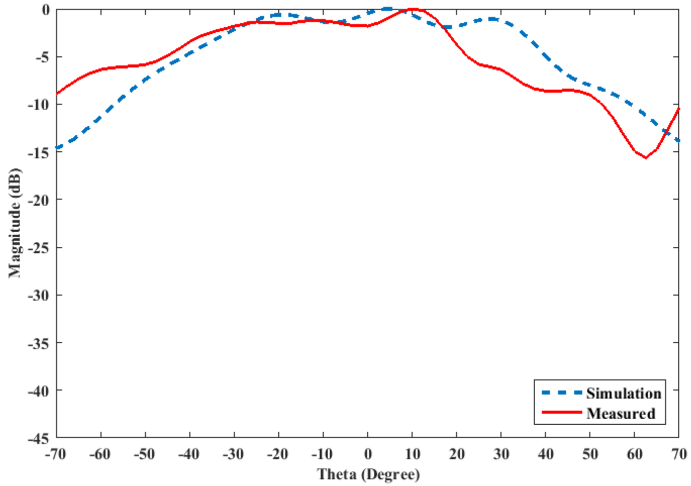


The 4x4 beamformed patterns, measured

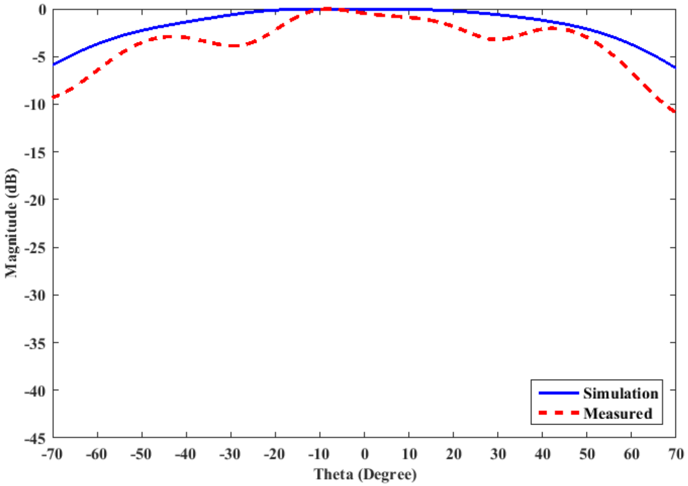




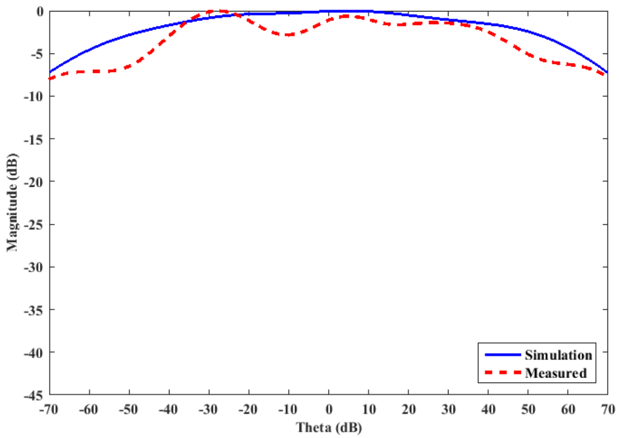
Measured immersed element patterns



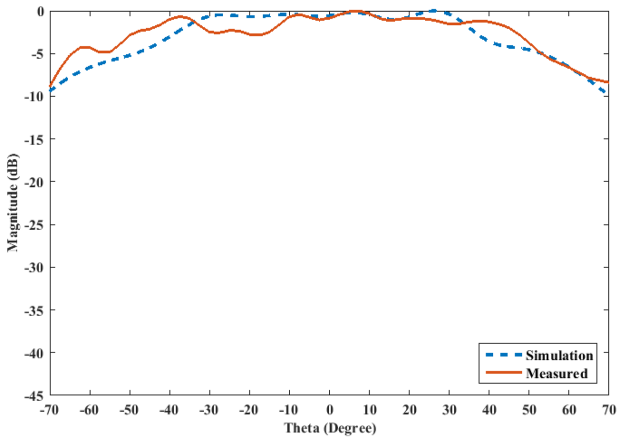
900MHz, E-plane



1400MHz, E-plane



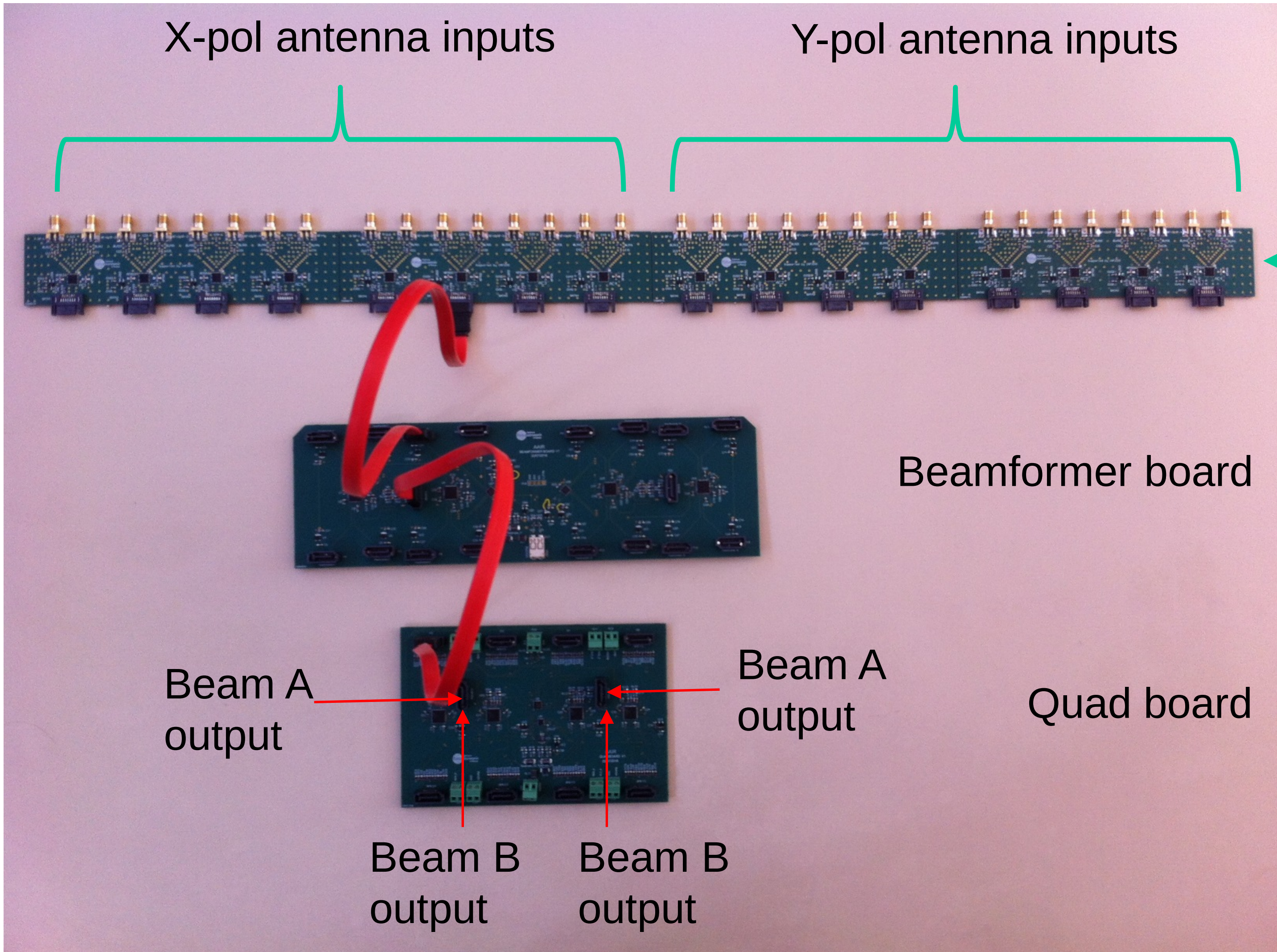
900MHz, H-plane



1400MHz, H-plane

The System Integration With Time Delay based beamformer

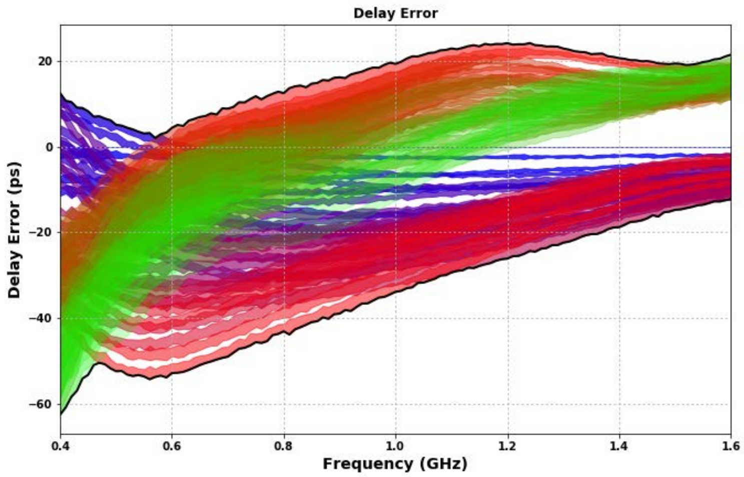
Time delay based beamformer solution for dual polarisation with two beams

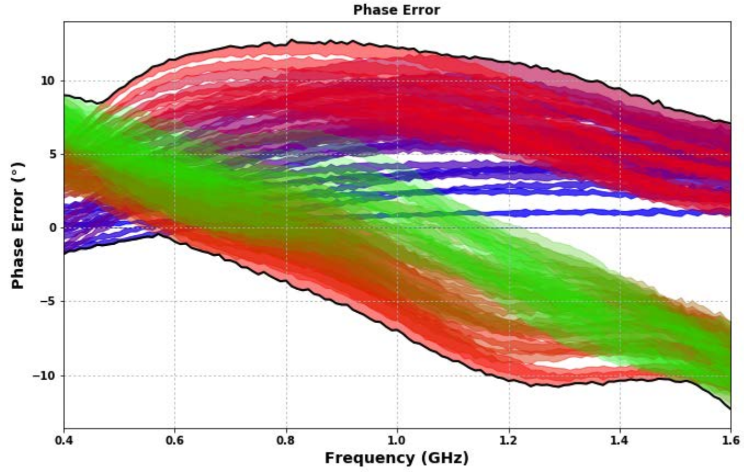


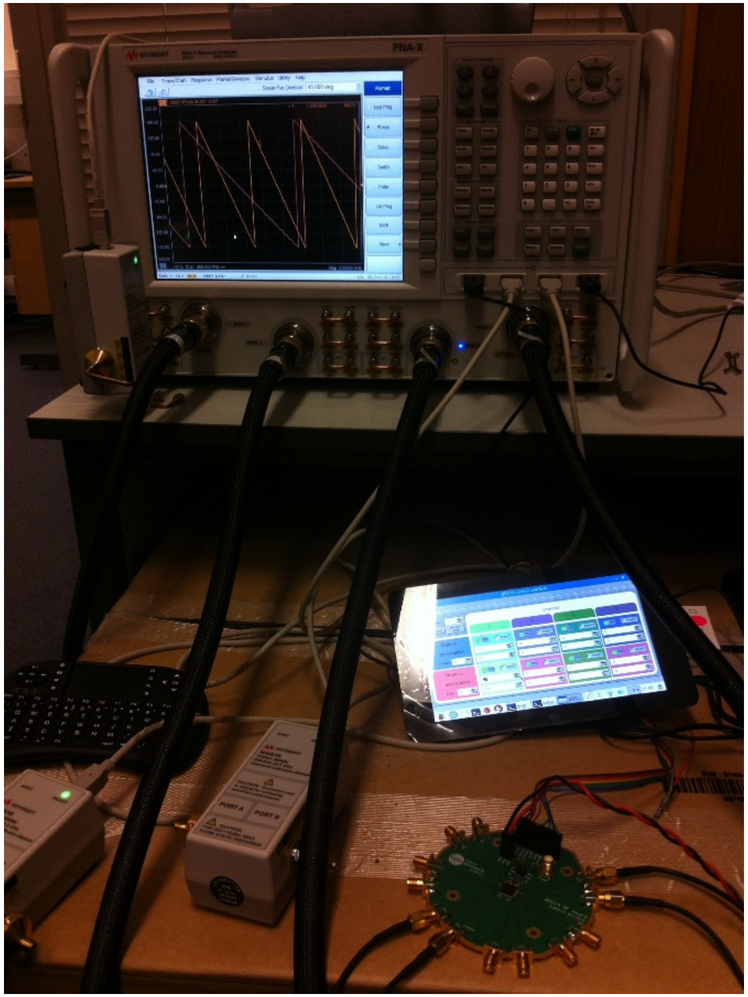
ORA filtering board

All boards are developed at Nançay

Beamformer Chip Performance

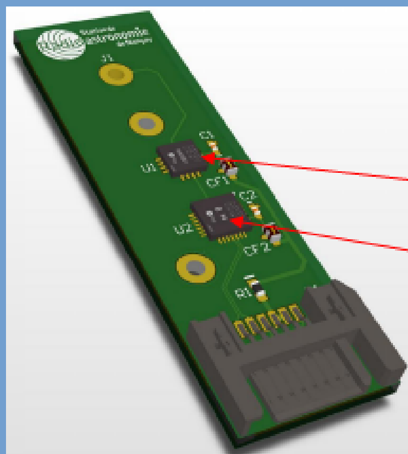






Front-End R&D
at
Station de Radioastronomie de Nançay
Observatoire de Paris

Feedmodule for Vivaldi antenna



Single-ended LNA

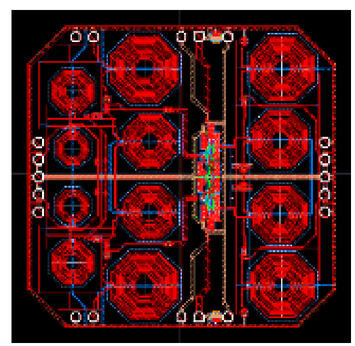
Active Balun Filter

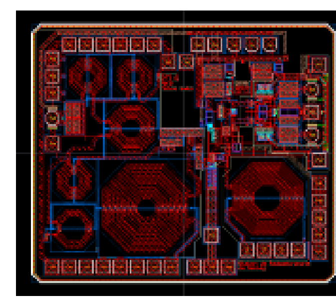
Feedboard for ORA antenna

Differential LNA

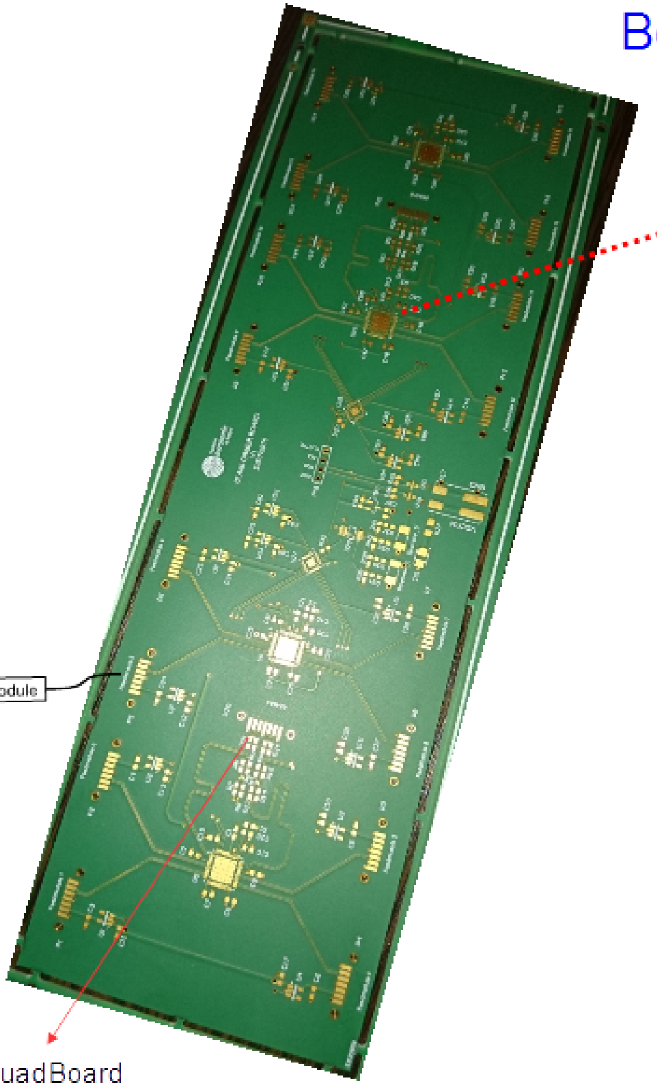
Developpements with SiGeC Technology :
Low noise amplifier (single or differential)
Filter
Active Filter
Active Balun
Passive component
Etc.

Aims :
Low noise
Low cost
Low power consumption
Smart





BeamFormerBoard



BDC :

ASIC 4 channels & 2 beams
- Time delay = 1,2ns * 2 = 2,4 ns
- Step = 20 ps * 2
- Error phase = ± 10 degrees
- Freq bandwidth = [400–1500 MHz]

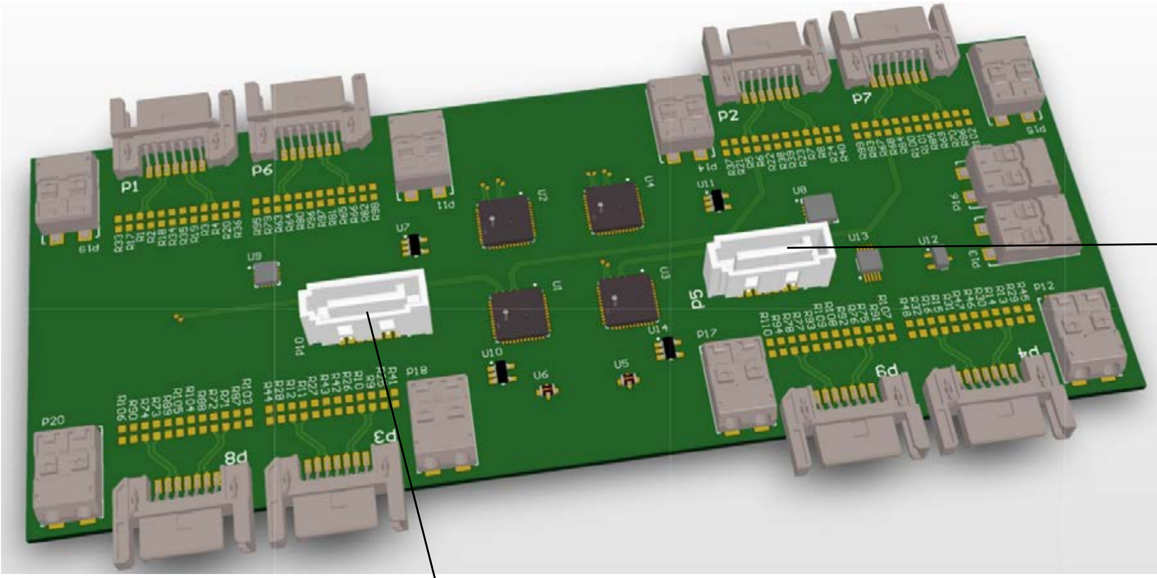
4 BDC / BeamformerBoard
→ 16 BDC for 0.5 m2

Available BDC = +300

Tests → BDC is OK
Performance tests is in progress and shows that it match simulation

BDC need for the concept :
- Nançay & LAB : 2 m² → 72 BDC
- ASTRON : 2 m² → 64 BFC
- ORA : 1 m² → 32 BDC
  - 80% * 100 = 80 BDC
  - 16 + 64 = 80 BDC

Quad Board



Y-pol, Beam A&B

X-pol, Beam A&B

<u>Adjustable time delay</u>

ASIC 4 channels

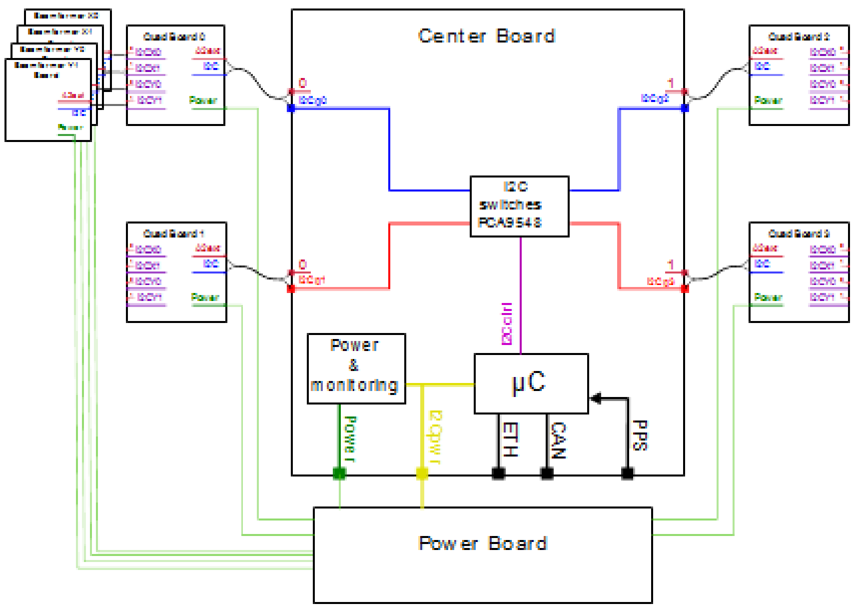
- Time delay = 1,2ns * 2 = 2,4 ns
- Step = 20 ps * 2
- Error phase = ±10 degrees
- Freq bandwidth = [400-1500 MHz]

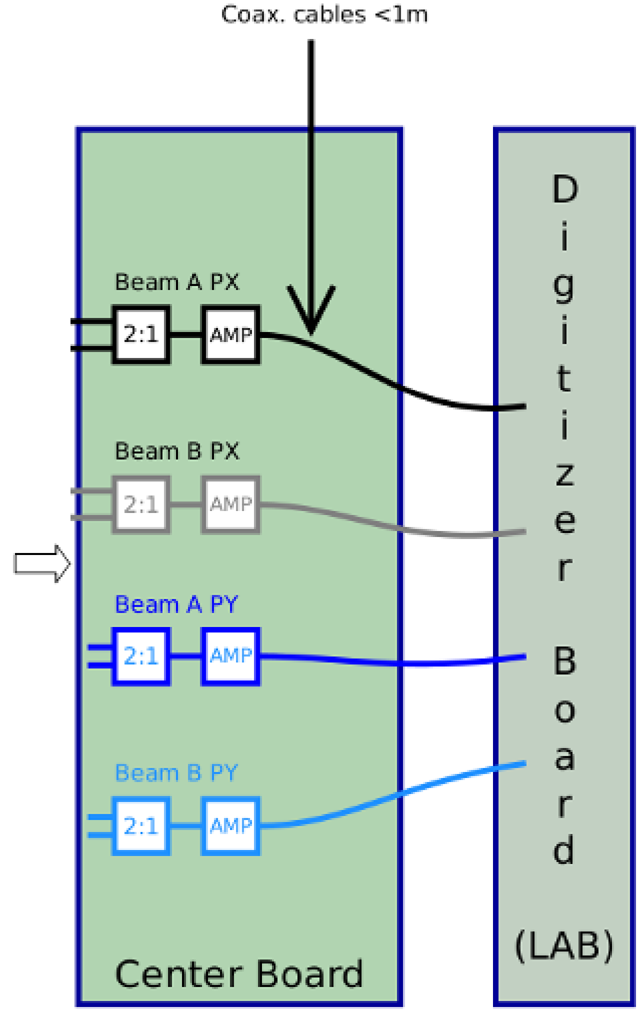
4 TD / QuadBoard

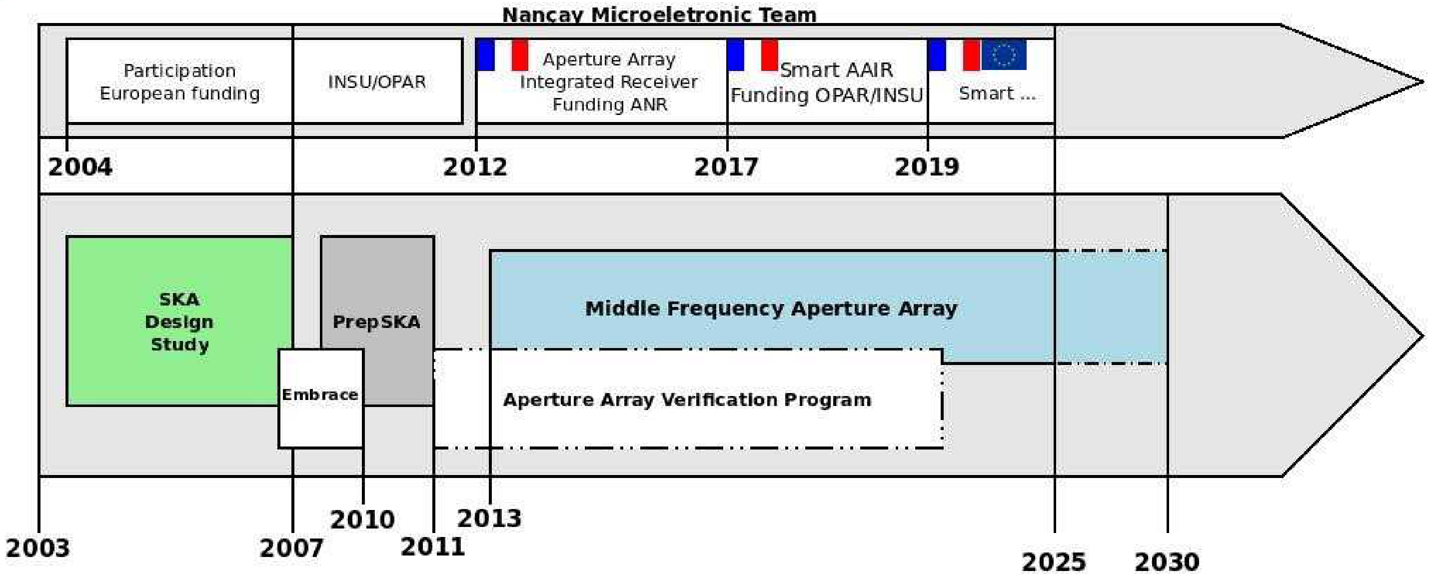
→ 8 TD for 2 m^2

Center Board

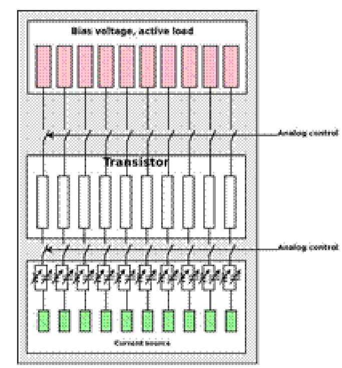
- Combines 2 QuadBoard per polarization
- Two polarizations are present on this board







- Smart -AAIR project:
  - Funded by Observatoire de Paris
  - Goal: Design and conception of smart IC with adaptive performance.
  - Context: design and study of new ASICs concept to have adaptive performance (gain, power consumption, intermodulation, …) versus requirement on the time of observation.

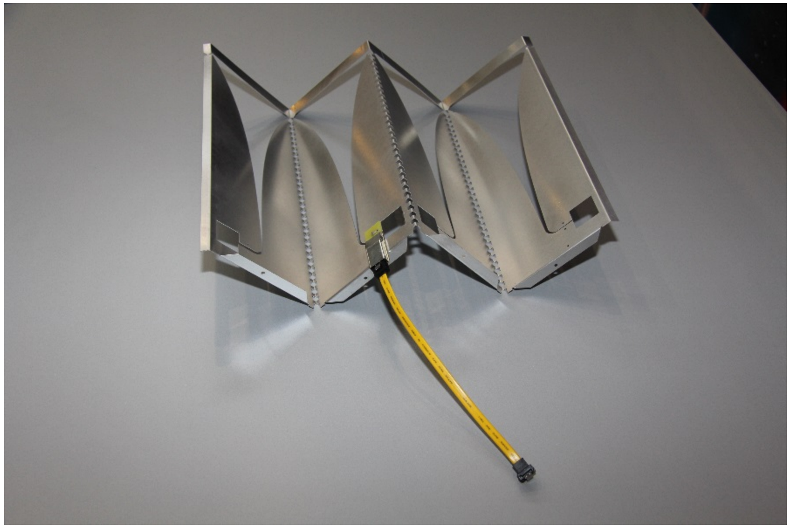


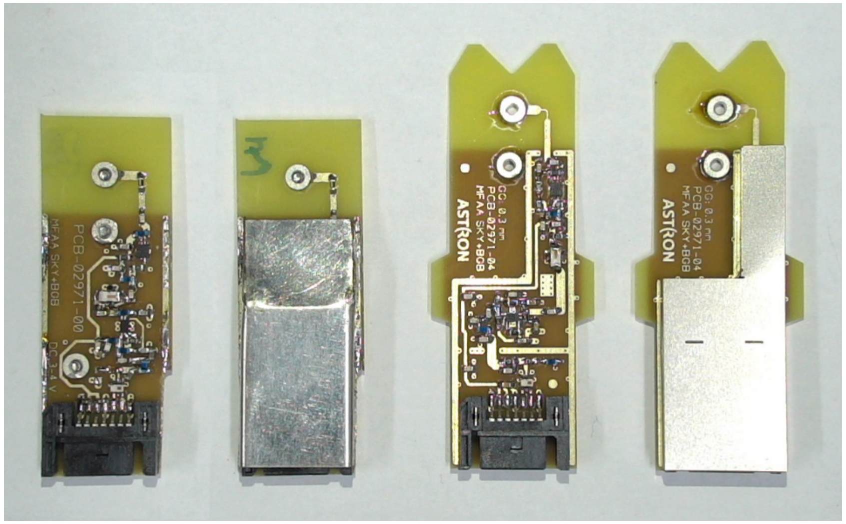
NEW LNA Topology

Single-Ended Front-End Development
ASTRON

Vivaldi Tile for MFAA

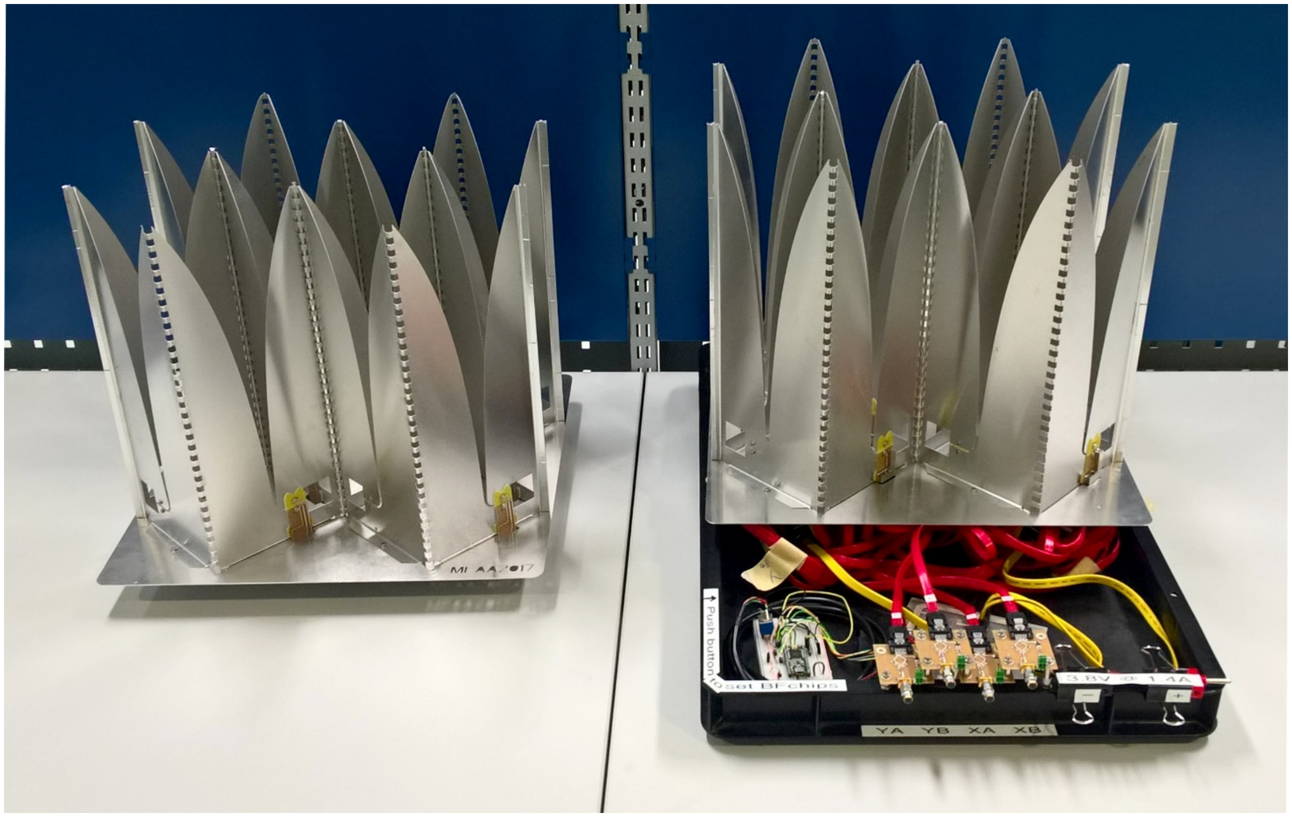
Active array with low noise solution





LNAs are integrated at the feeding points,
SATA interface to the beamformer board

Dual polarisation two beams beamformer

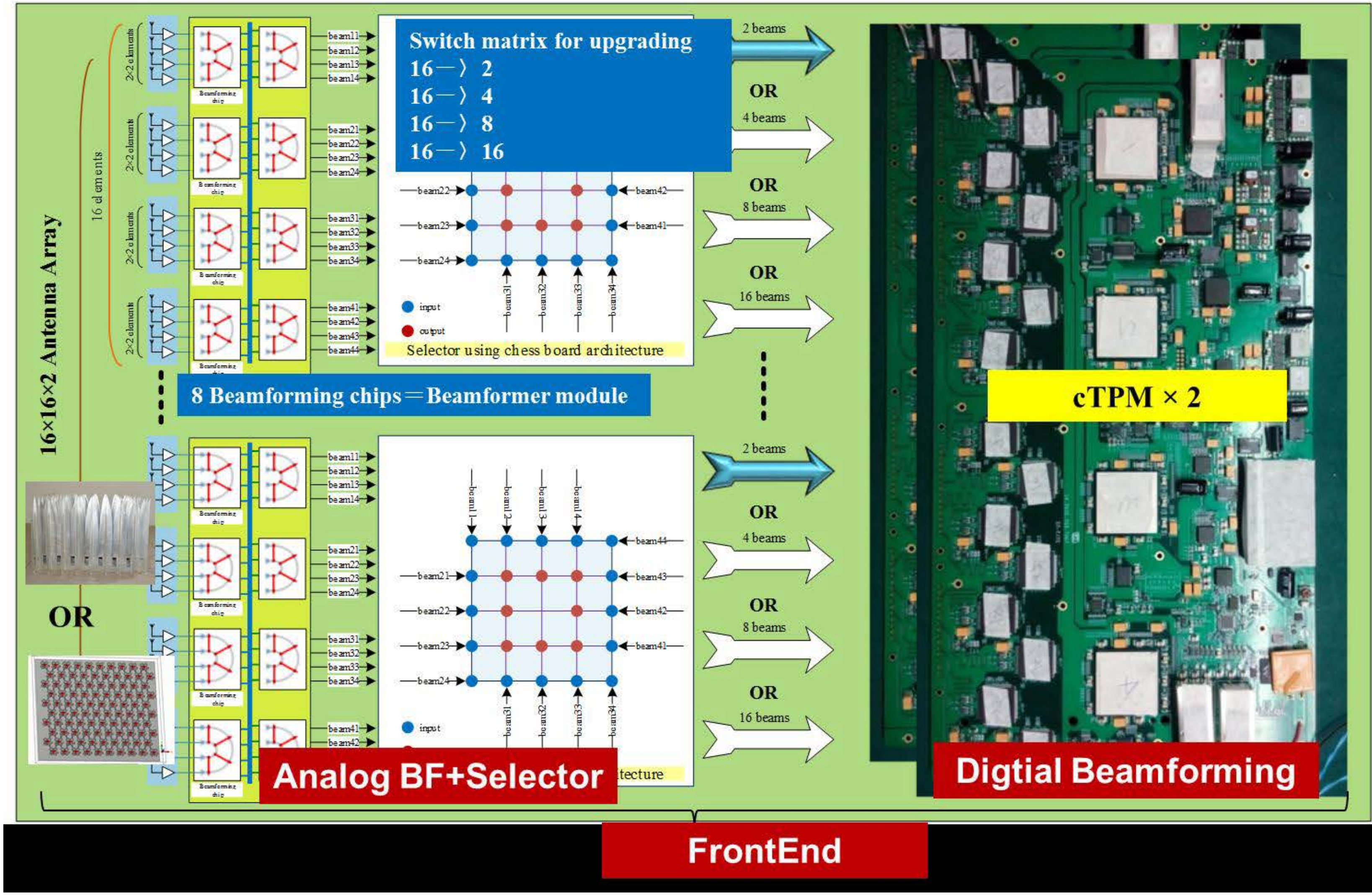


8 elements beamformer PCB for dual polarisations
2 beams for X polarisations
2 beams for Y polarisations

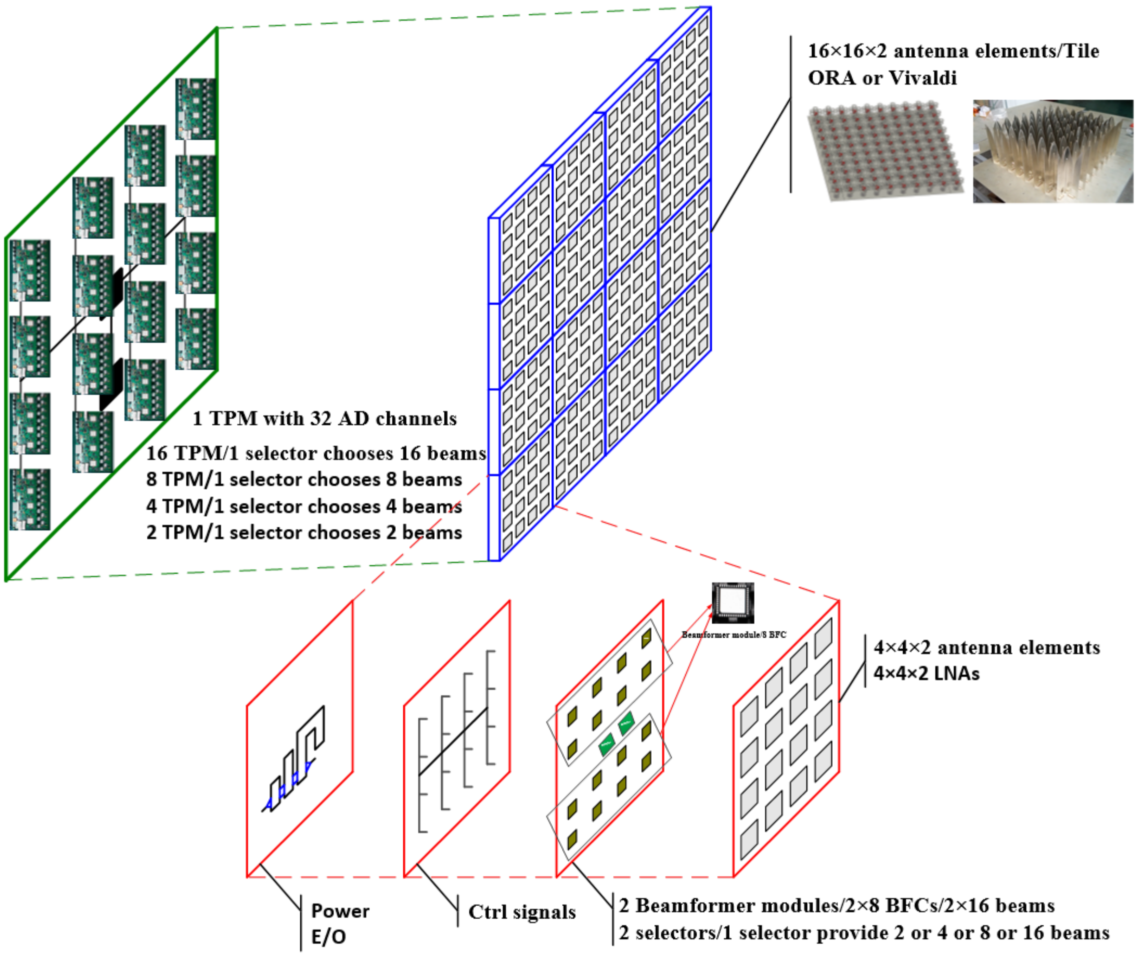
Single-Ended Front-End Development
KLAASA

Key Lab of Aperture Array and Space Application

Architecture

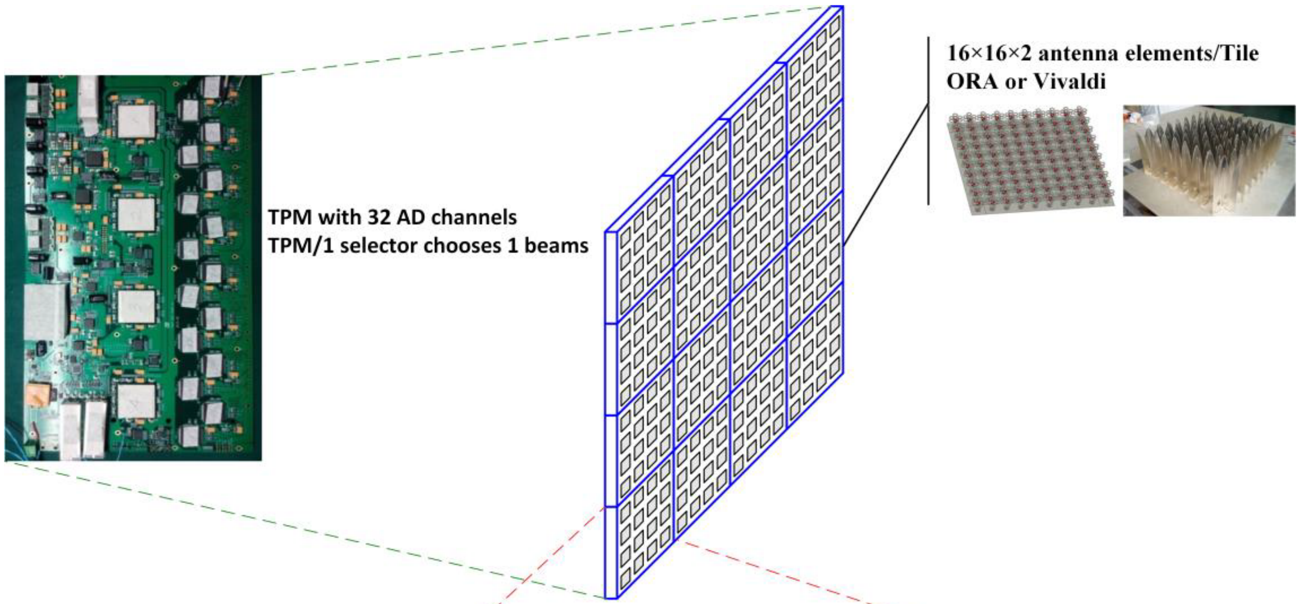


4x4 to 1 analogue beam configuration

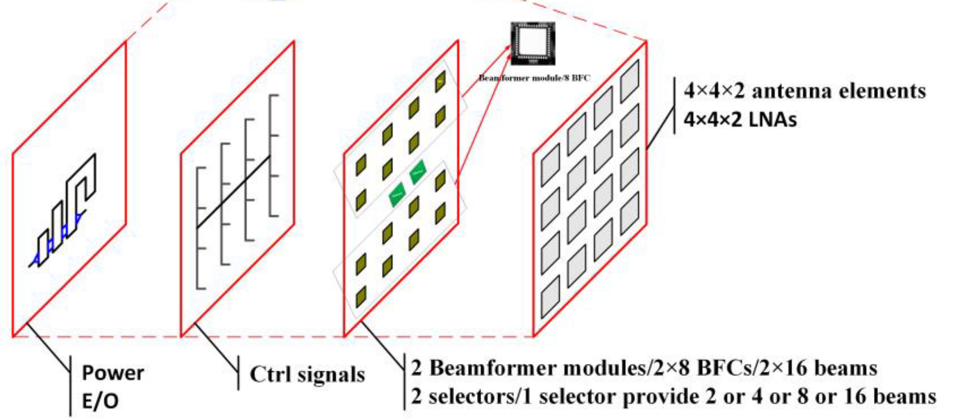


- 4x4 output 1 analogue beam
- 16x16x2 tile will generate 32 beams
- 1 CTPM can process 512 antenna elements

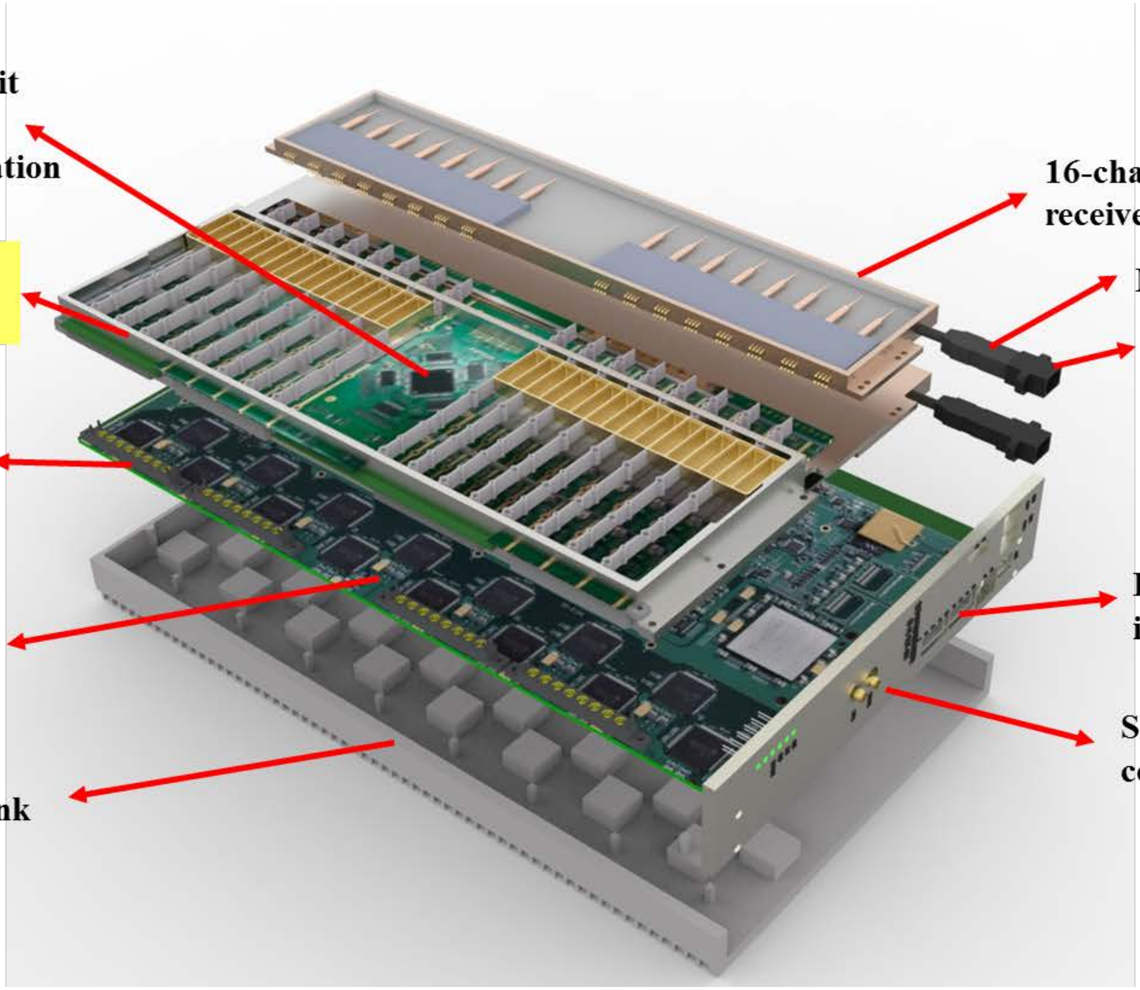
4x4 to 16 analogue beams configuration



- 4x4 output 16 analogue beam
- 16x16x2 tile will generate 512 beams
- 16 CTPM can process 512 analogue beams

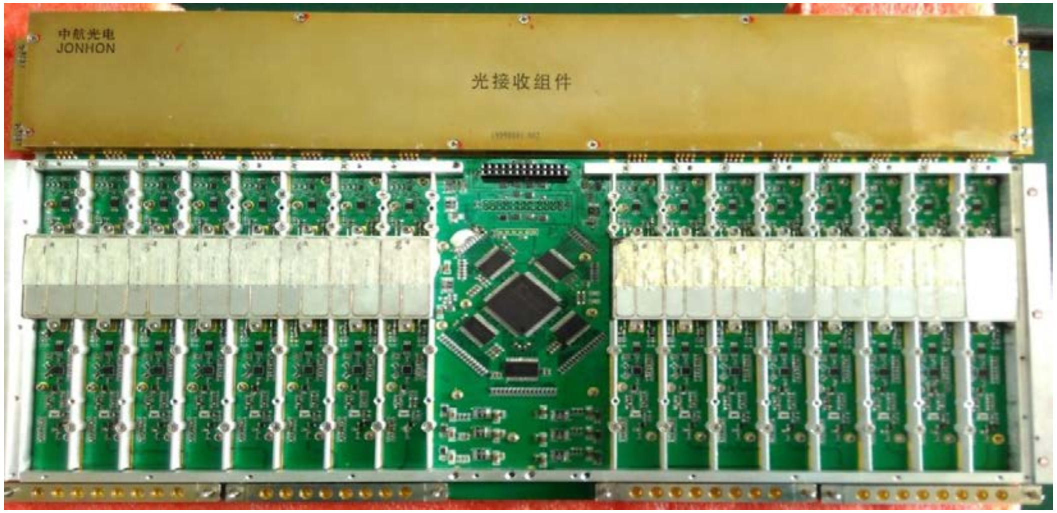


CTPM with three layered structure



Prototyping

KLAASA has completed the test of V1.0 For LFAA

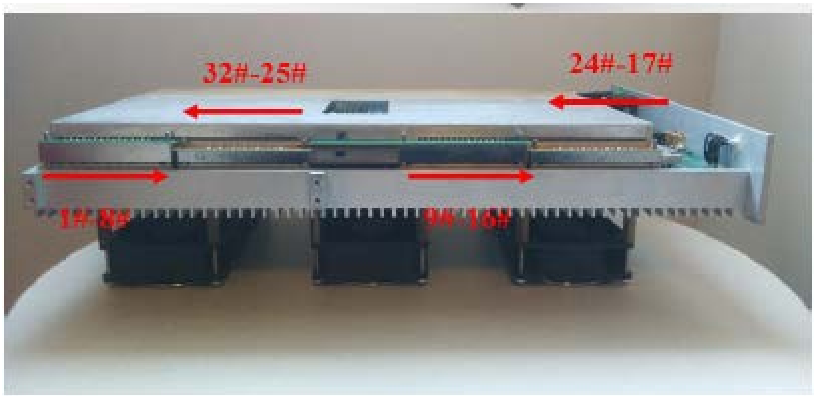


32 channels with optical receivers

32 AD channels Processing

CTPM for MFAA

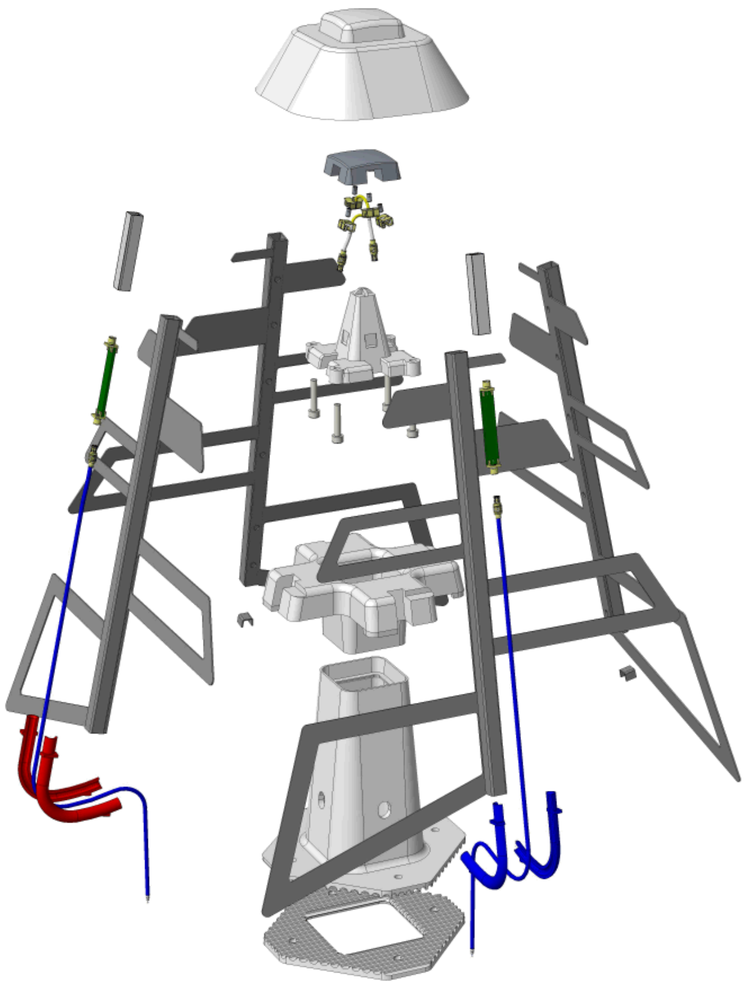
Frequency	500MHz-1500MHz
Rx Channels	32
Band width	400MHz(700MHz-1100MHz)
Amplitude Flatness	≤±1.5dB (Rx)
Band Suppression	≥40dB (Rx)
Attenuator	4bit, 1dB step
Power supply	DC -48V
Digital Output	40Gb/s
Adjacent frequency channel suppression	60dB
Power consumption	≤120W
Size	≤233.35mm×430mm×50mm

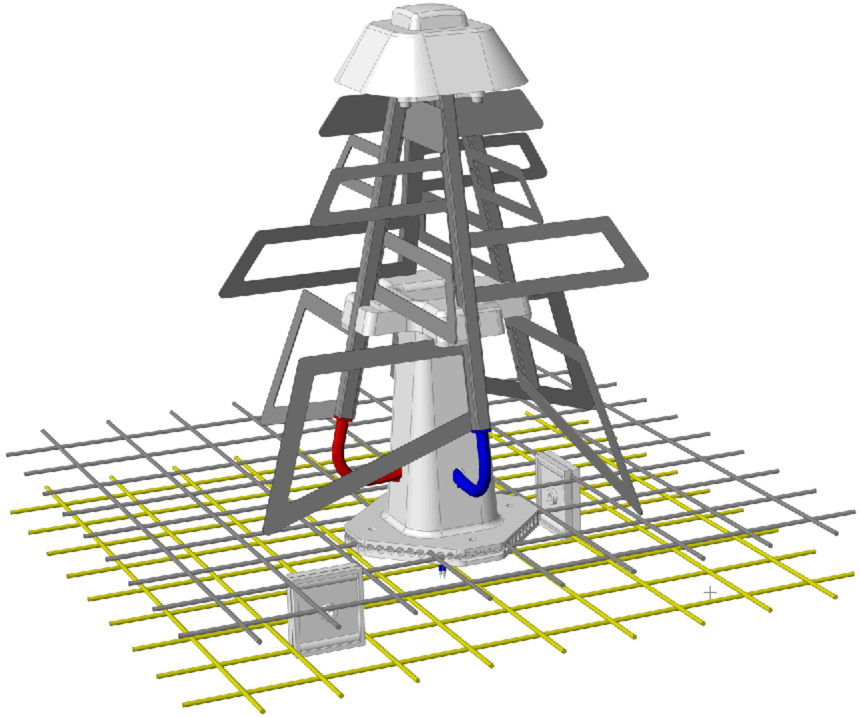


Log-Periodic Dipole Antenna for SKA-AAMid (Sparse Array)

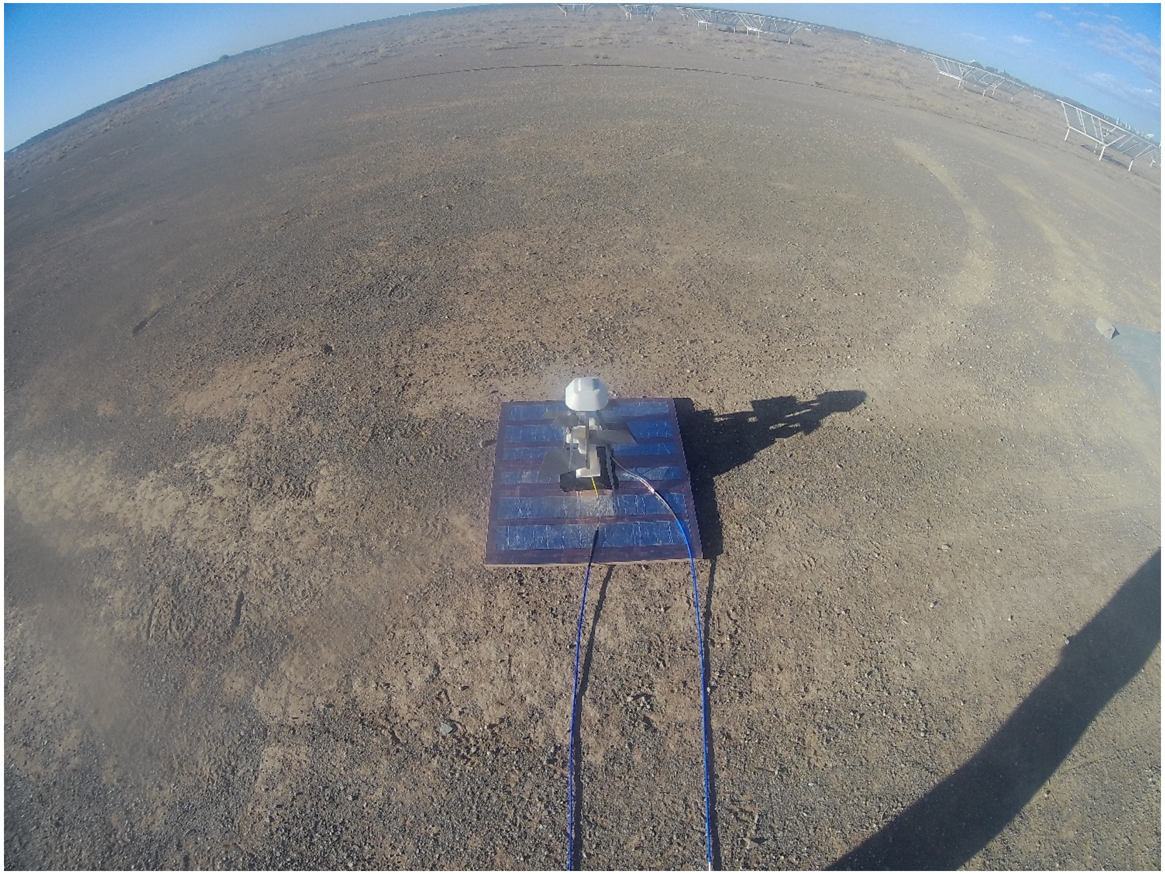
UNIVERSITY OF CAMBRIDGE

Log-Periodic Dipole Antenna for MFAA





LPDA for MFAA and LNA



Tile demonstrator at Lord's Bridge

Summary

- Different front-end technologies become more mature
- Dual polarisation with dual beams per polaristation can be realised with phase shift or time delay based analogue beamforming
- High polarimetry performance can be achieved
- Irregular distribution of elements in the array, random thinning techniques can be explored to further reduce the total number of elements

Thank you