AAMID Front-End Design

David Zhang – The University of Manchester
Roel Witvers – ASTRON
Hao Qin – KLAASA
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Edgar Colin – University of Cambridge

Outline

- Front-End Design Team
- Review of Front-End Design for SKA AAMID
- Current progress status
- Forward Project Planning
- Closer Collaboration regime

The Front-End Design Team

Front-End Design Team

Front-End Design Task Leader
David Zhang
The University of Manchester

ASTRON

- <u>Roel Witvers</u>
- Benedetta Fiorelli
- Pieter Benthem

KLAASA

- <u>Rui Cao</u>
- Hao Qin

O de P Nancay

- <u>Sangitiana Rako</u>
- Stéphane Bosse
- Severin Barth

UMAN

- <u>D. Zhang</u>
- Ming Yang
- Ahmed El-makademal
- A. K. Brown

UCAM

- *<u>Edgar Colin</u>*
- *Andrew Faulkner (LNA)*
- *Eloy Acedo*

Front-End Design Sub-teams

Selection Criterion Document Writing Team

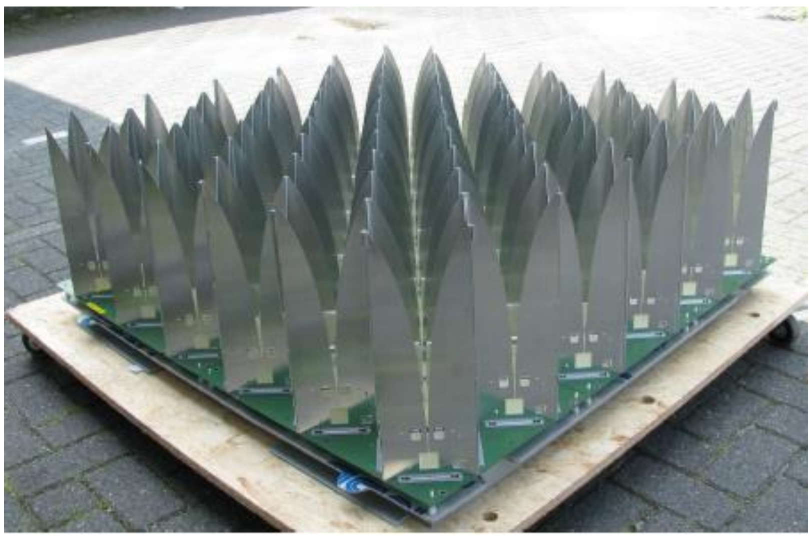
D. Zhang/M. Yang
Roel Witvers/Benedetta Fiorelli
Rui Cao/Hao Qin
Stéphane Bosse/Sangitiana Rako

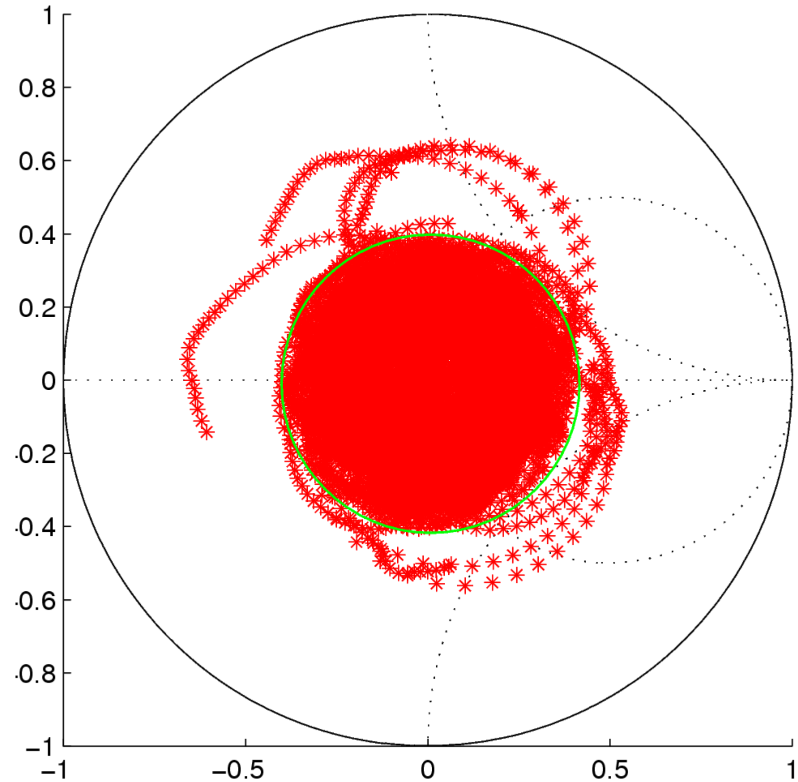
Measurement Team

D. Zhang/M. Yang
Roel Witvers/Pieter Benthem/Benedetta Fiorelli
Rui Cao/Hao Qin
Stéphane Bosse/Sangitiana Rako

Review of Front-End Design for SKA AAMID

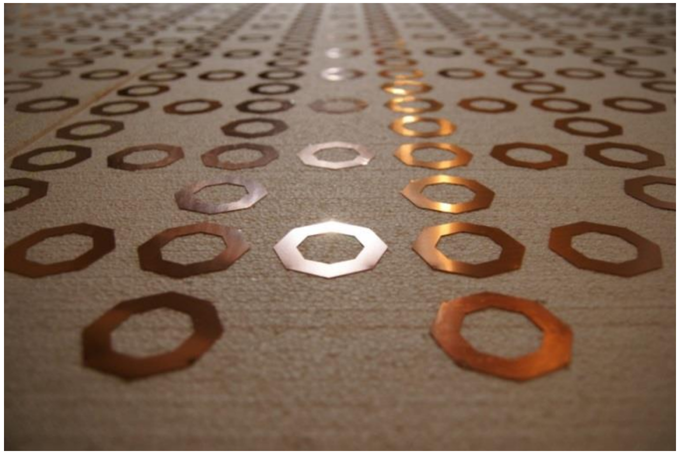
EMBRACE Designed by ASTRON

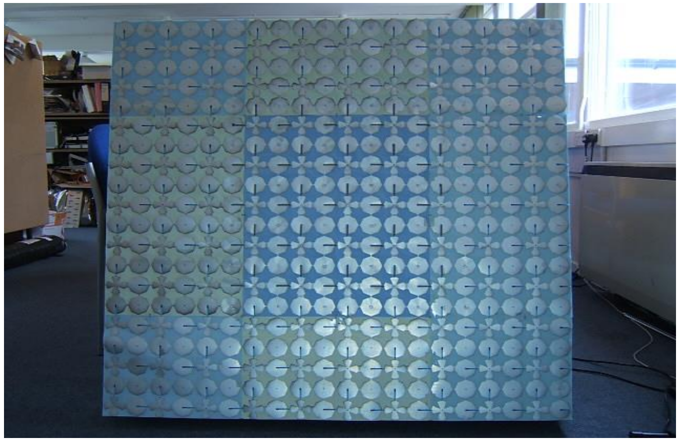


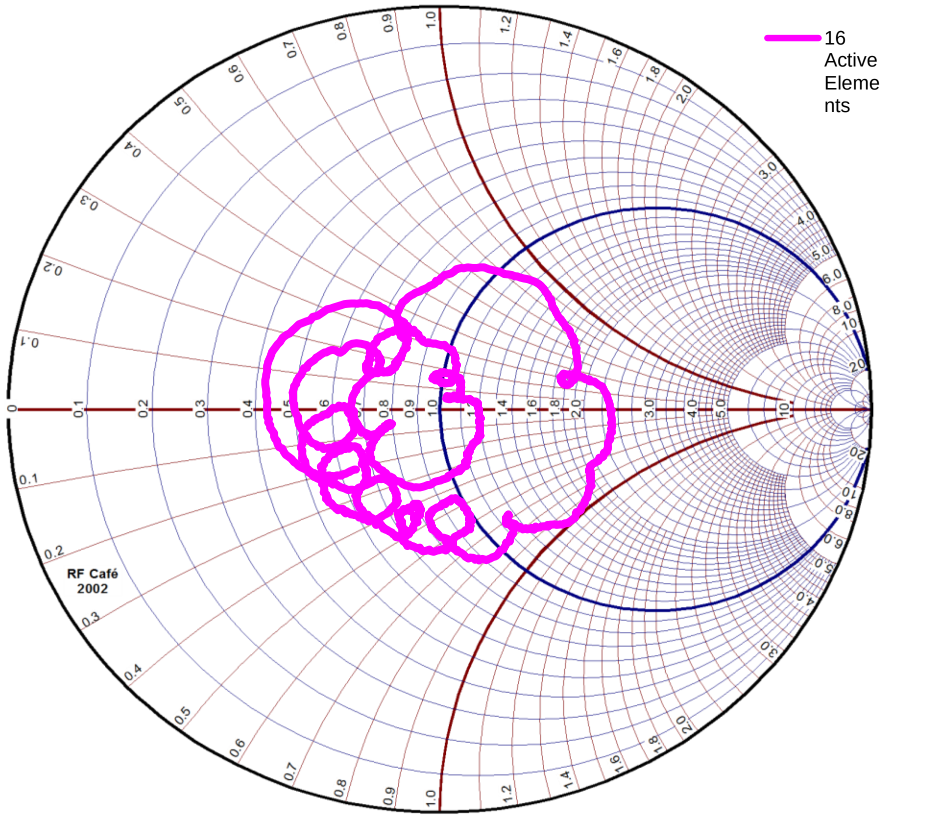


72 elements become active, and the active input impedance for the centre element

Finite ORA Array

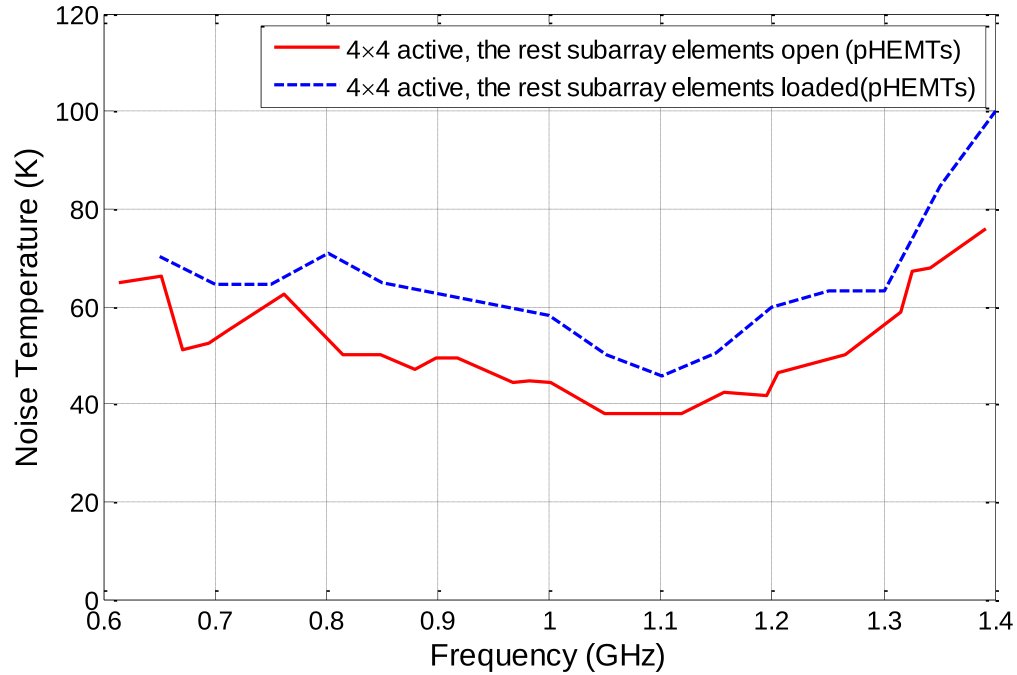






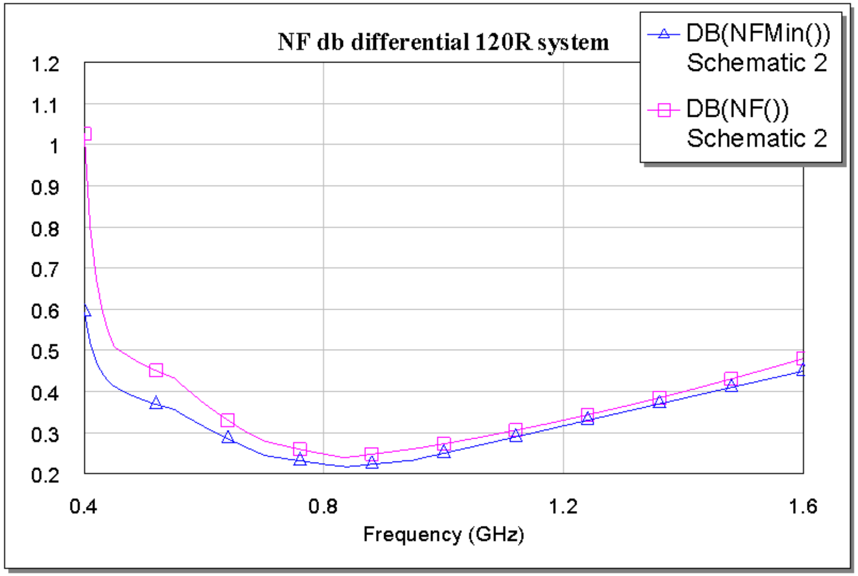
4 x 4 elements become active, and the active input impedance for the centre element

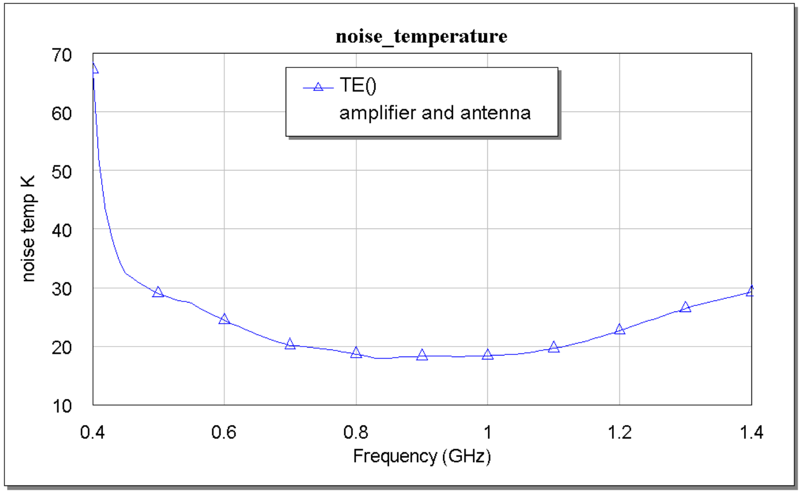
ORA with Manchester LNA

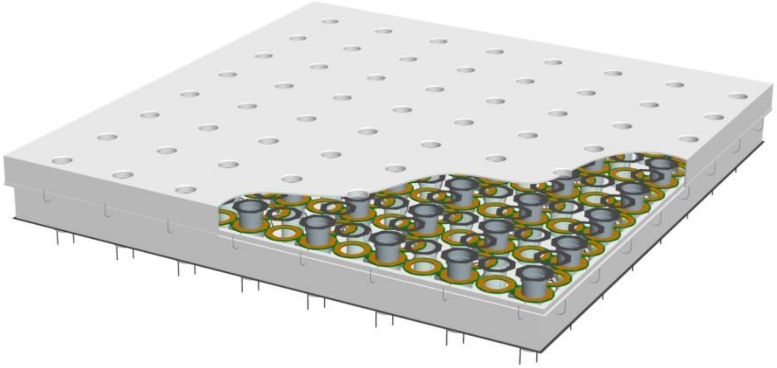


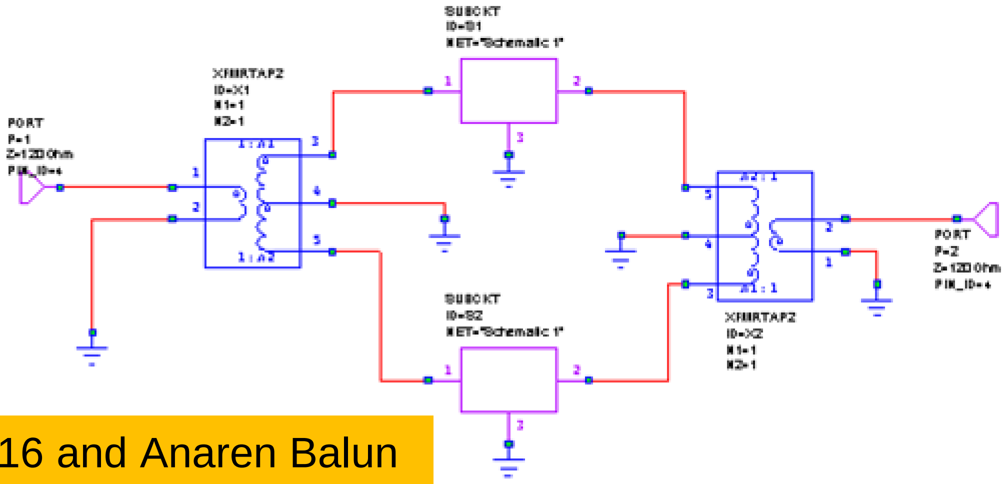
Noise measurement with a 4x4 beamformer

ORA with AVAGO LNA (CCL)







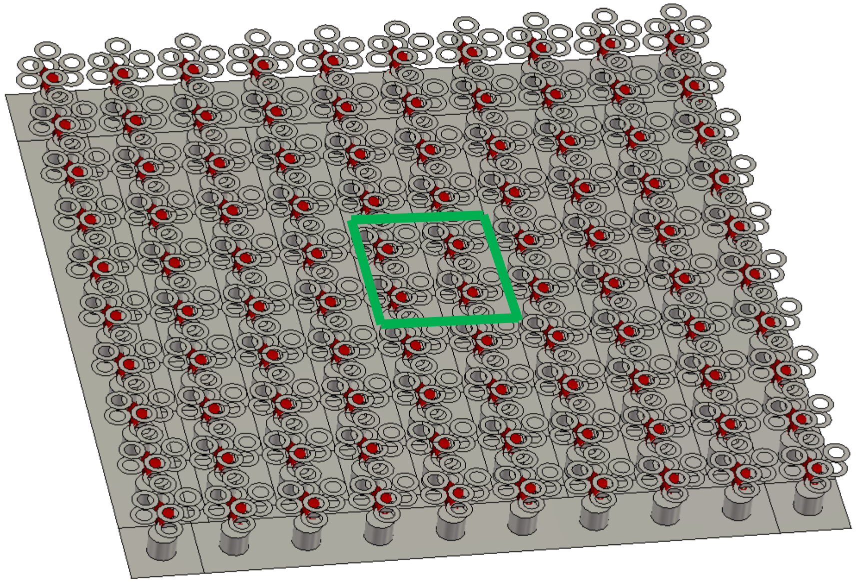


Simulation based on the AVAGO MGA16116 and Anaren Balun

The Current Status

Manchester

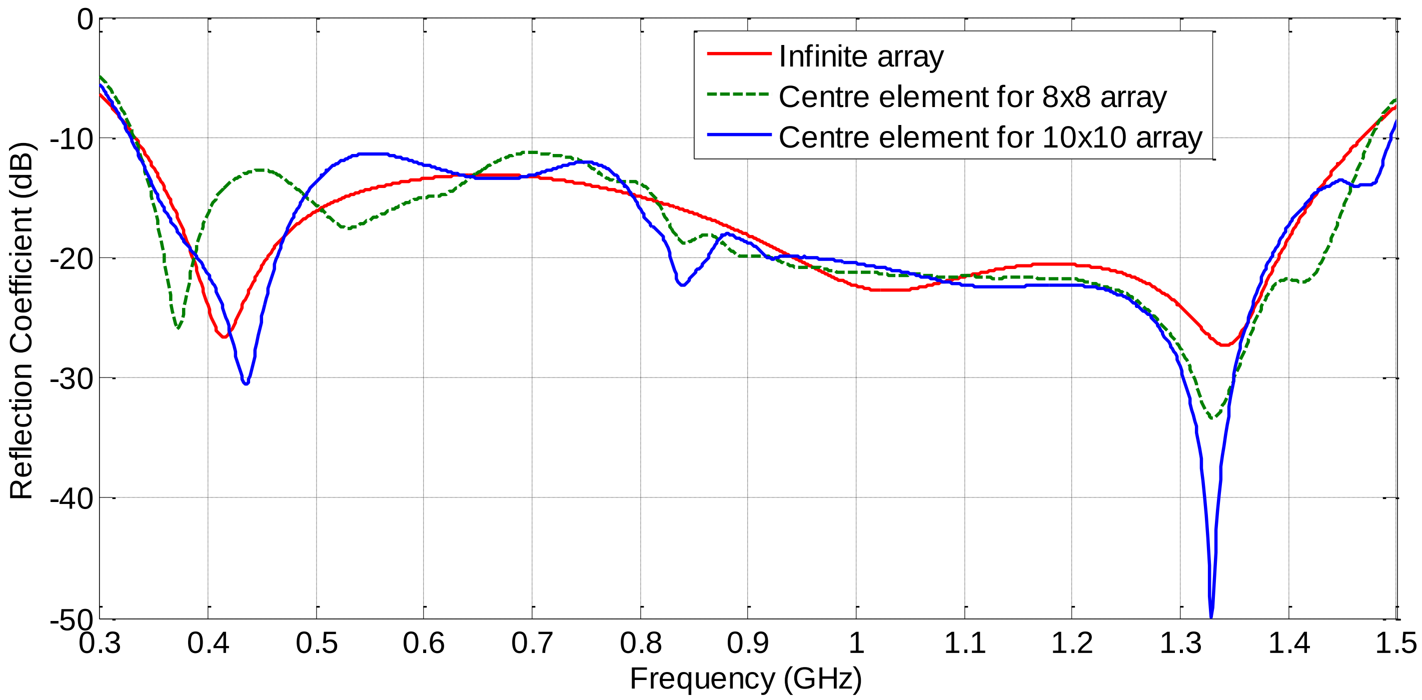
The Manchester Antenna Design



Element spacing for the current design: 125mm
Frequency band: 350-1450MHz

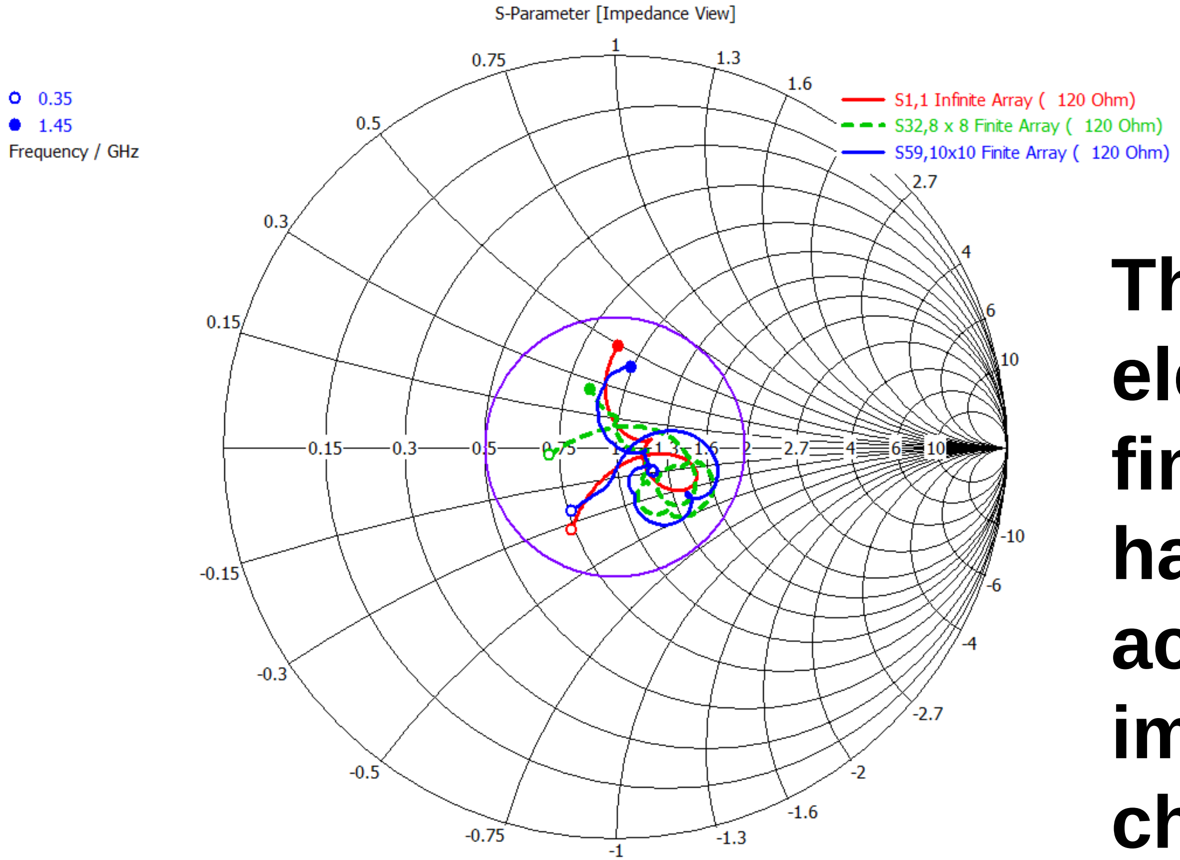
The array aperture needs a certain size to have immersed elements demonstrating a similar EM performance as in an infinite array

Finite Array Simulation



8 x 8 and 10 x 10 finite arrays are simulated, indicating a minimum aperture size of 1 m^2 is required for the initial prototype panel

The active input impedance



The centre element of 10 x 10 finite active array has a similar active input impedance characteristic as in an infinite array

ORA Technology for Aperture Array

- The Octagonal Ring Antenna (ORA) represents a novel and potentially breakthrough technology using a planar, easily fabricated structure for dual polarised wideband aperture array
- Stable cross polarisation performance over wide scan angle in broad frequency range
- The fundamental Electromagnetics have been confirmed. The applications can be other than radio astronomy
- Three patents for ORA has been applied for, one granted to date

ASTRON

Outline

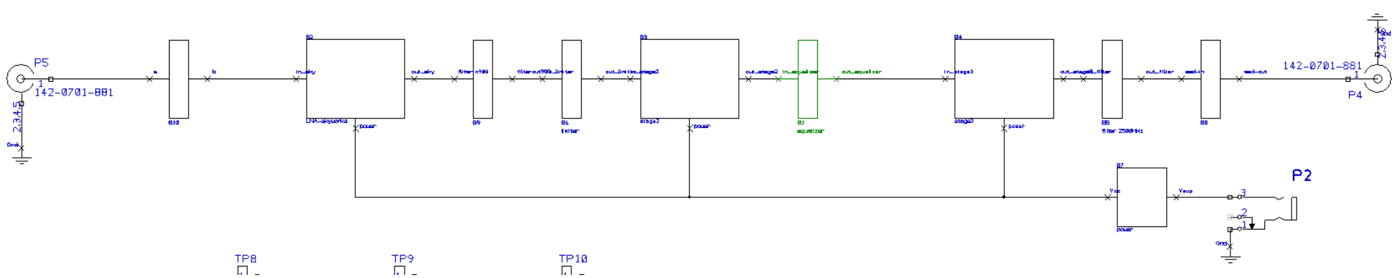
- Outline
- Low Noise Tile goals
- LNT board results
- 2x2 array results
- Wideband LNT design
- First results
- Conclusion

Low Noise Tile

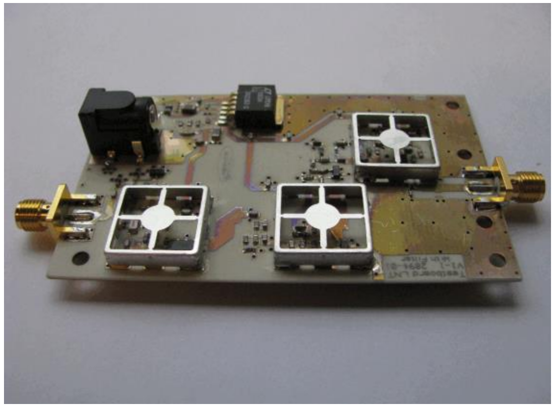
Goals:

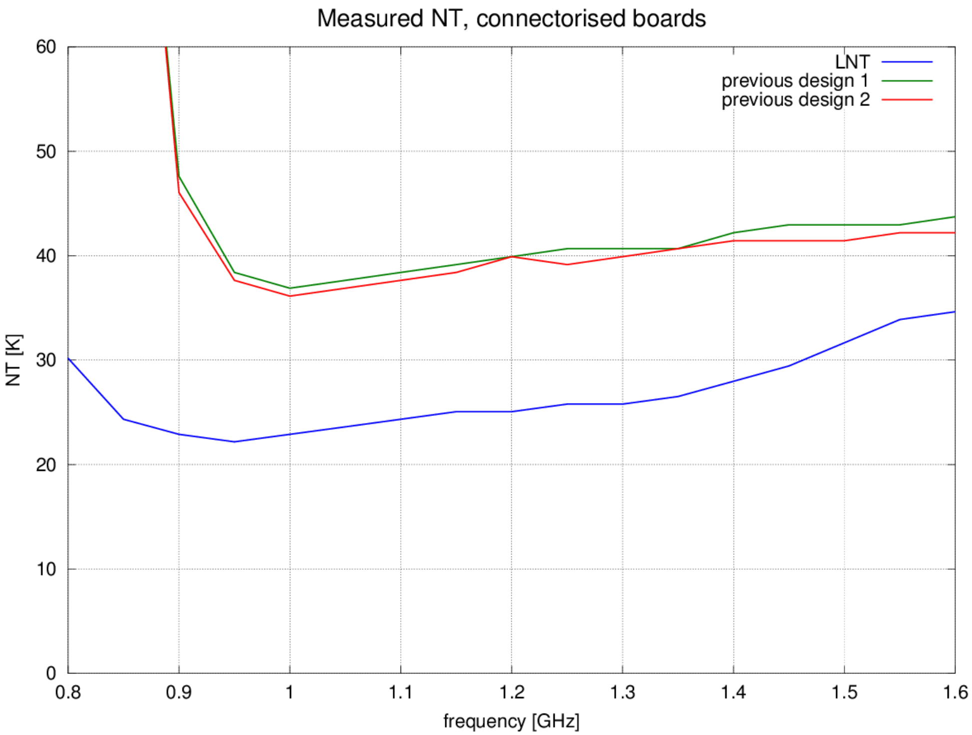
- **Improve NT of Phased Array Tile**
- **New LNA board design**

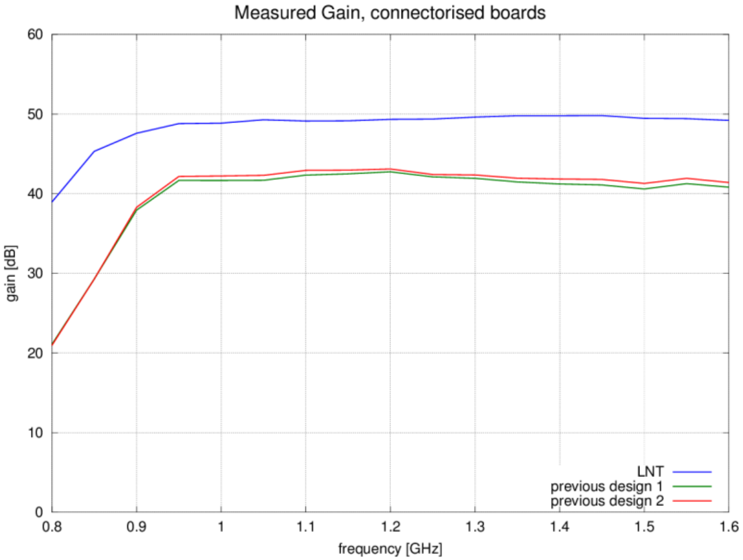
Frequency range	**1.0-1.75 GHz**
Noise Figure LNA	**< 25K**
Gain LNA	**>20dB**



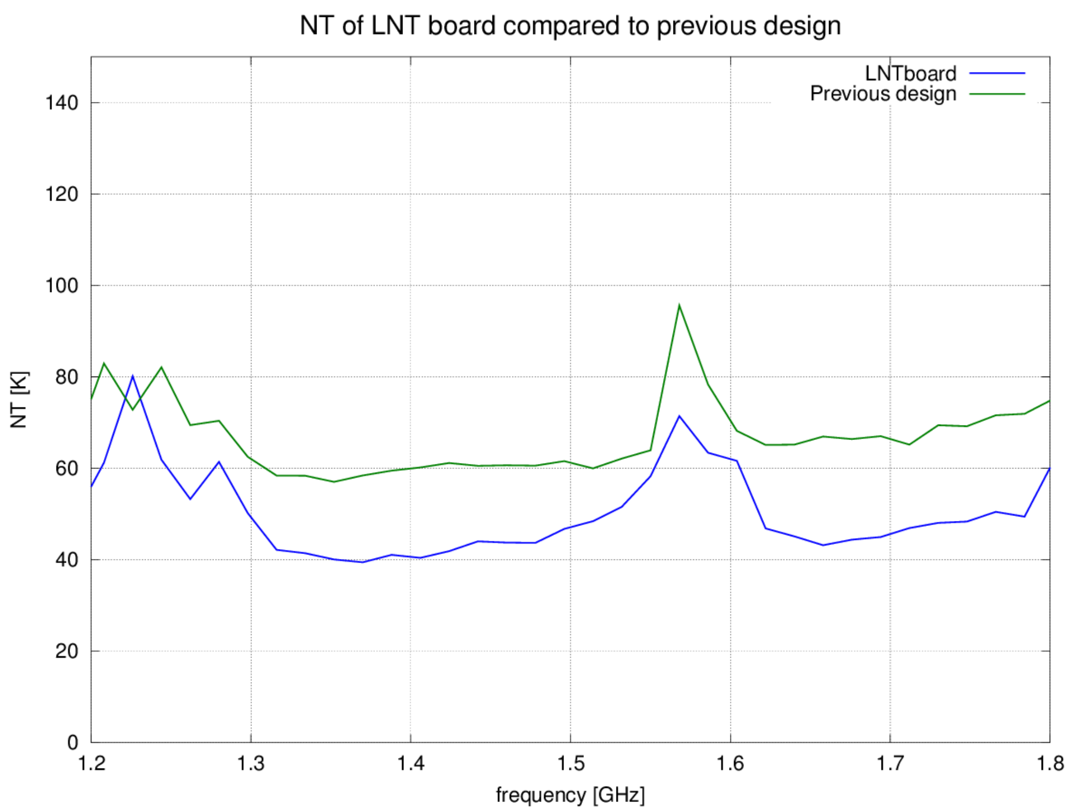
Low Noise Tile Connectorised board



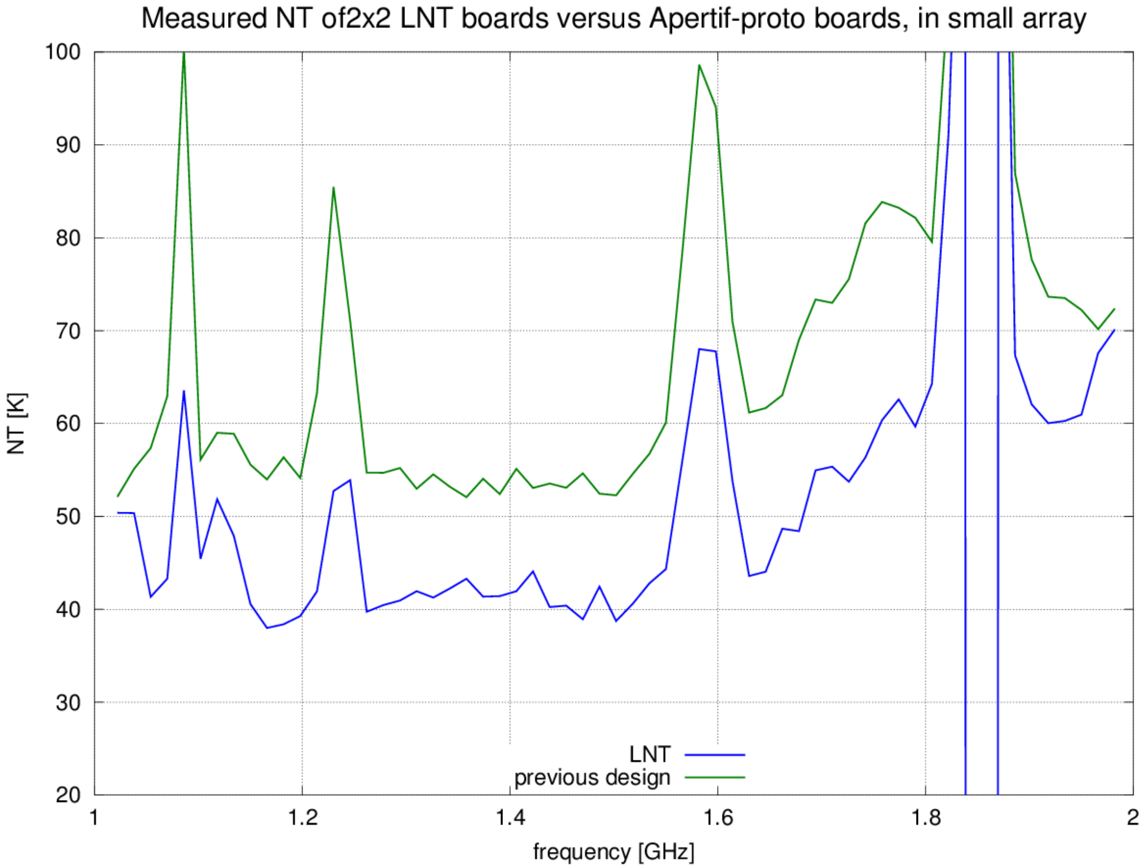




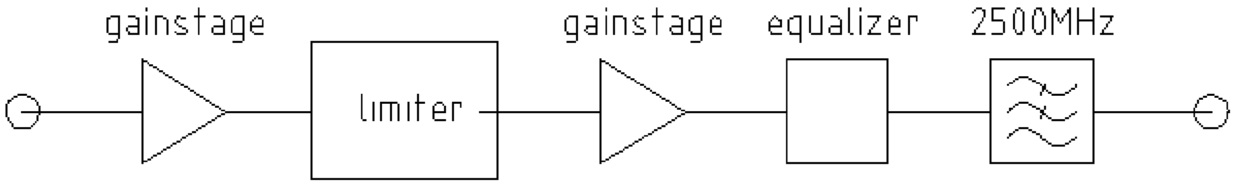
Low Noise Tile
Single Element Results

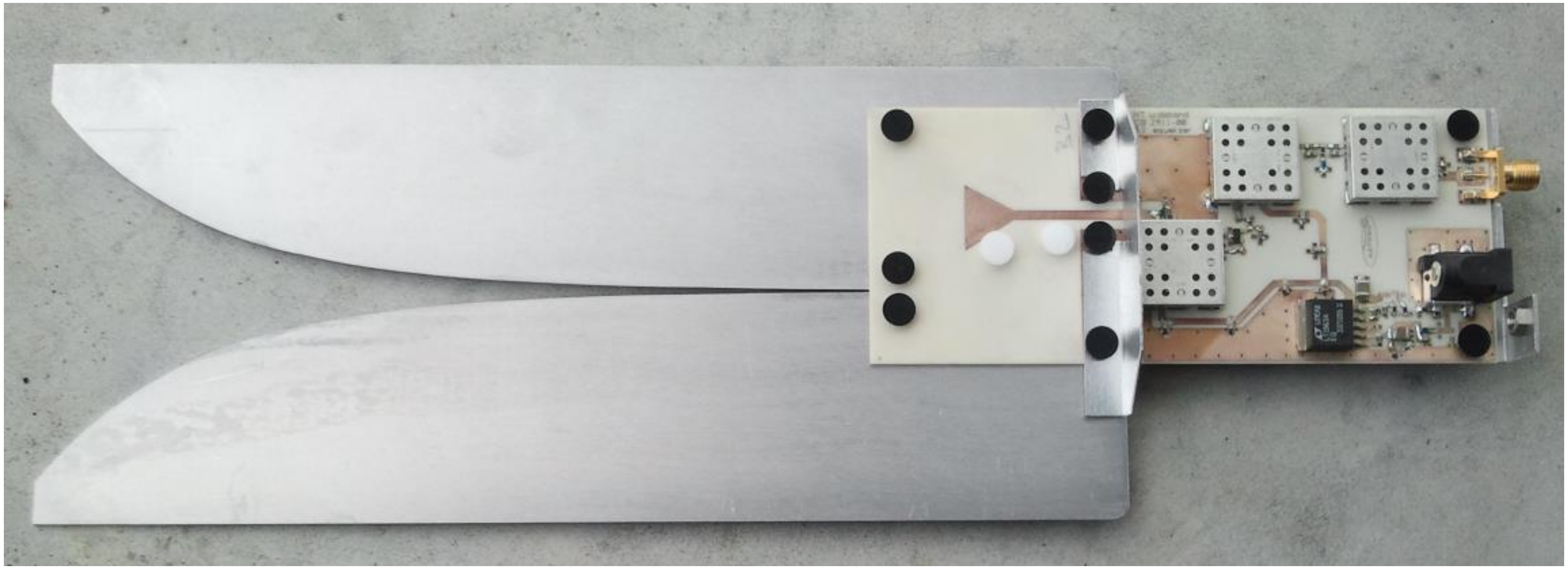


Low Noise Tile
2x2 array results



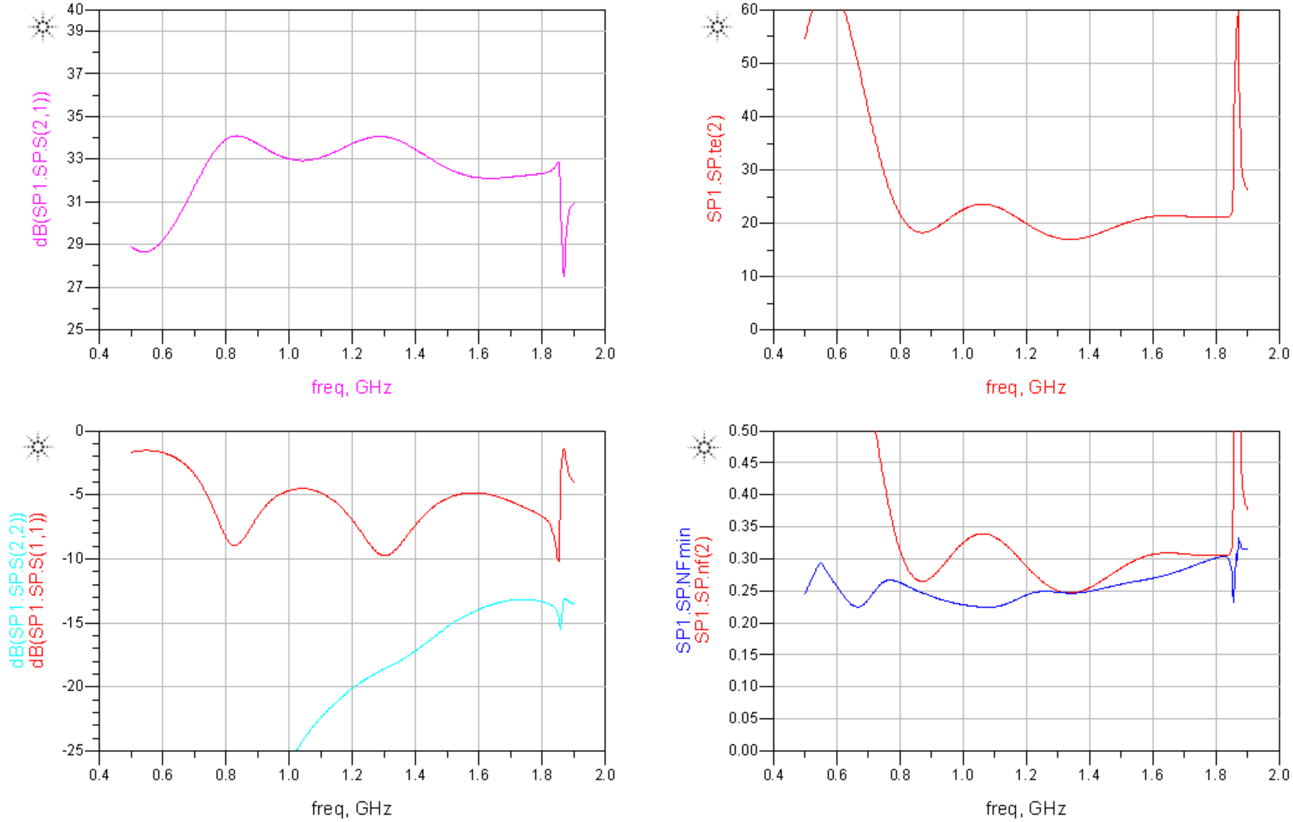
Wideband LNT





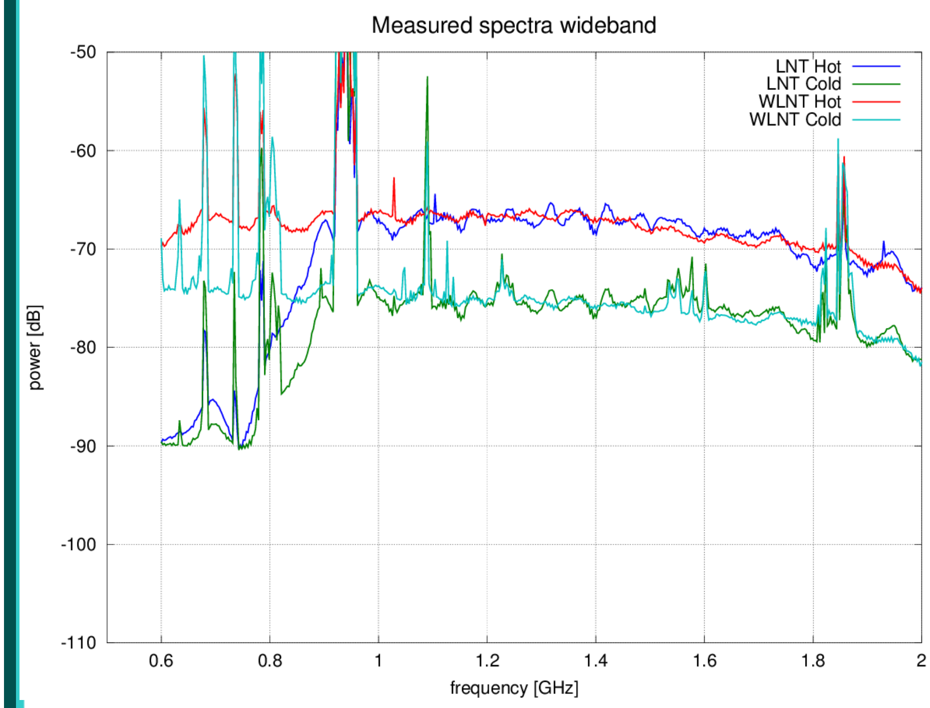
Wideband LNT simulations

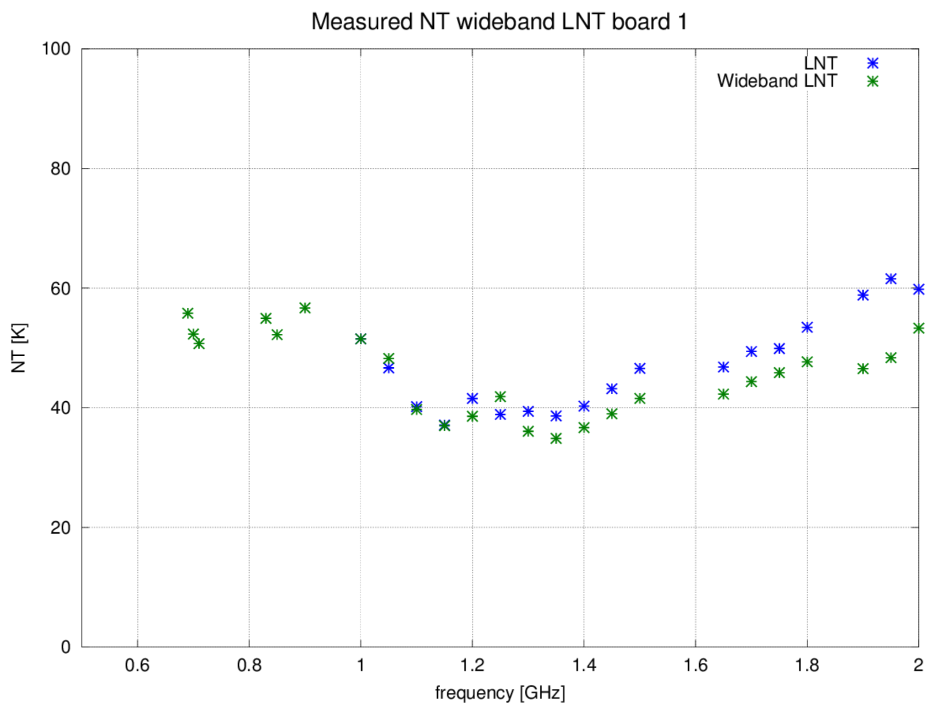
Simulation Wideband LNT board
Antenna at input



including filter,
no limiter

Wideband LNT first results





Corrected for skynoise

Conclusion

- LNT gives 15K improvement over previous design
- Wideband LNT board gives promising results below 1GHz
- Present Apertif antenna element useable from 750MHz

To Do:

- Tuning of design for lower NT below 1GHz
- LNT and Wideband LNT need to be measured in an Array (LNT will be measured soon at Parkes)

KLAASA

KLAASA/CETC38 SKA（MFAA）

The Square Kilometre Array

Exploring the Universe with the world's largest radio telescope

CETC38

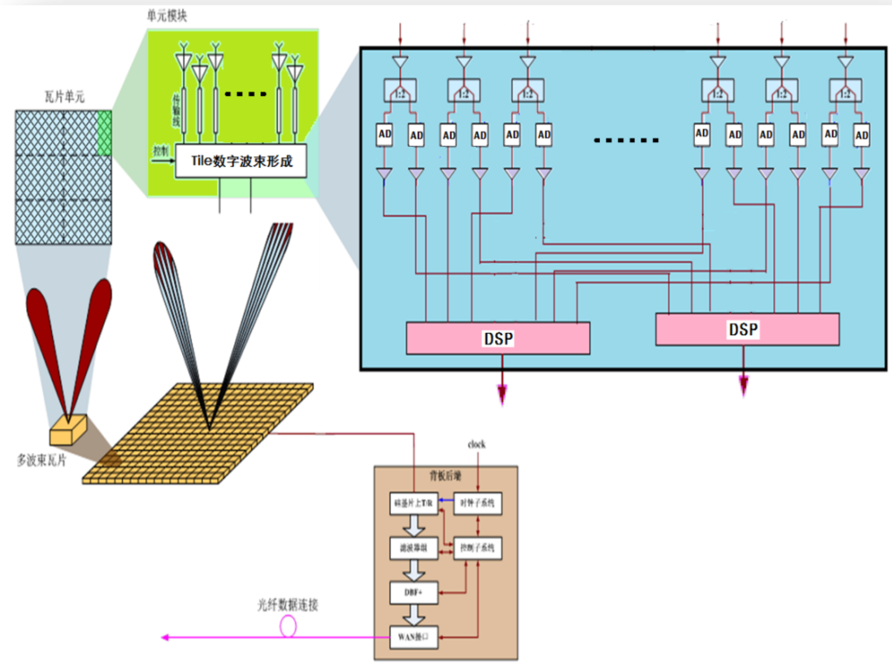
02/04/2014

Outline

- Work carried out in KLAASA
- Low-temperature-noise test
- optical/electric transceiver
- LNA
- What to do next

AA-mid Architecture

■ AA-mid project



Dual polarized dense array

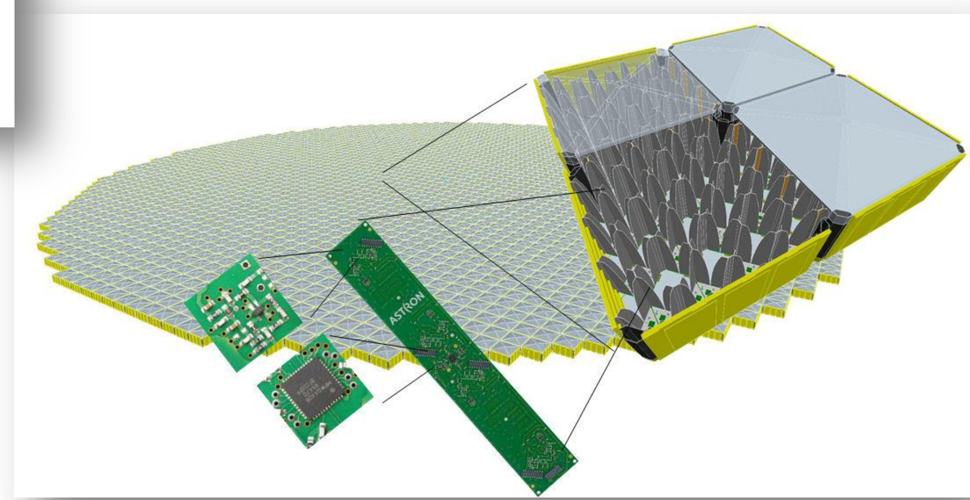
Direct time-delay(IPD)

High-level integration

- Tile:16*16 units, analogue beamforming
- Station: 430 Tiles, digital beamforming, diameter=35 m

High performance

- ADC and DSP chips developed by KLAASA: low power consumption and high performance
- Key issue: Tile-level calibration → basic for station-level and system calibration

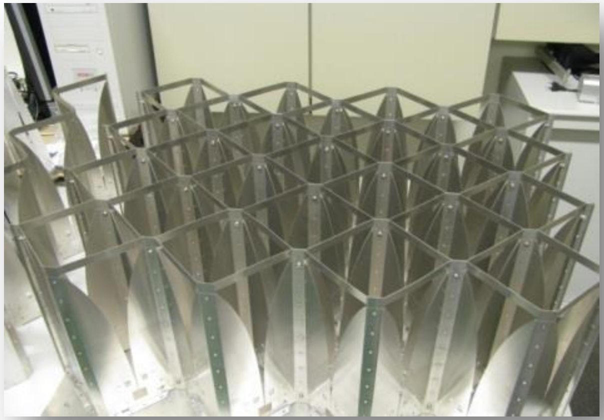


Main point：analogue + digital BF (ADC and DSP1042 of KLAASA)

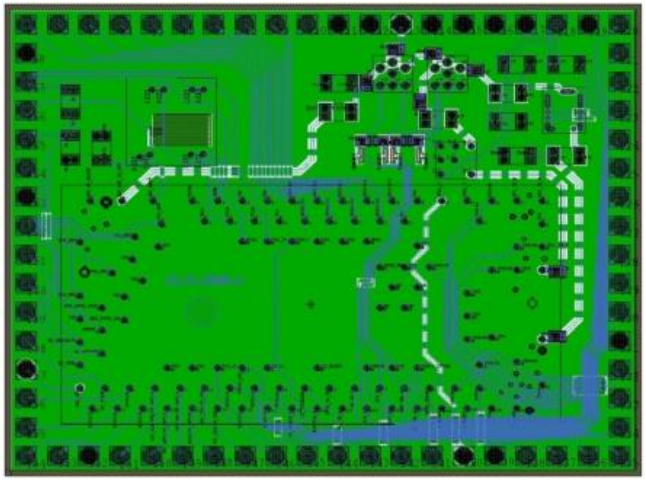
Initial Prototype

■ AA-mid: Current Progress

- Frequency: **300-1600 MHz(300-1000 MHz)**
- No. receiver channels:**16/tile**
- NF: **≤0.7 dB(50 K)**
- Range: **≥40 dB (single channel)**
- Ripple in band: **≤2 dB**
- Channels coherence:
  - ✓ Amp. : **≤0.5 dB (rms)**
  - ✓ Phase : **≤ 5.0° (rms)**
- BW: **250 MHz**
- Way of cooling: **natural**
- Connectors: **Voltage supply 5V, optical transport data rate 10 G/S**
- Reliability: **SKA requirement**
- Temperature requirement: **-40℃～+50℃**



1.5m×1.5m double-polarized vivaldi antenna array



The delay-line based on Integrated Passives Device technology

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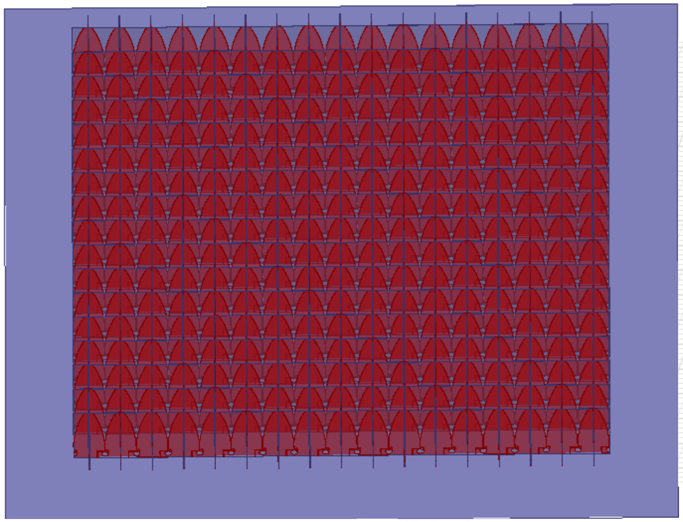
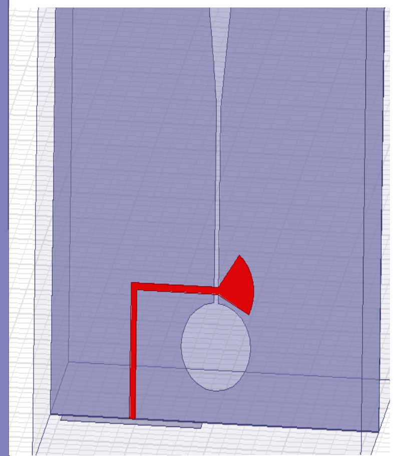
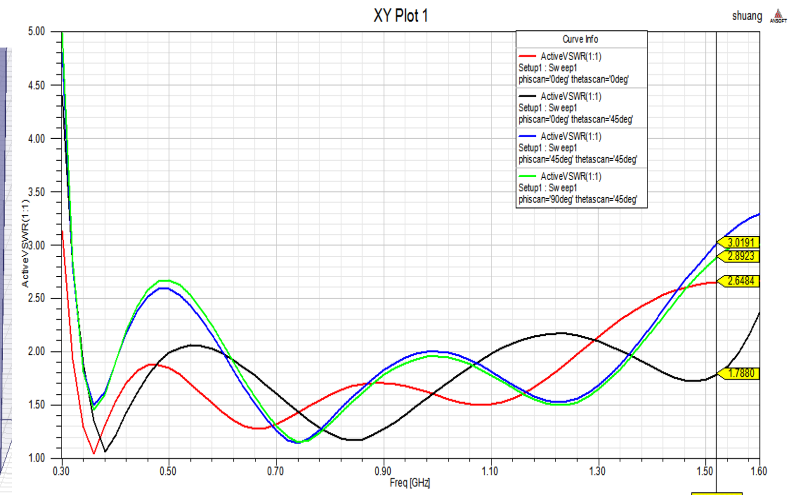
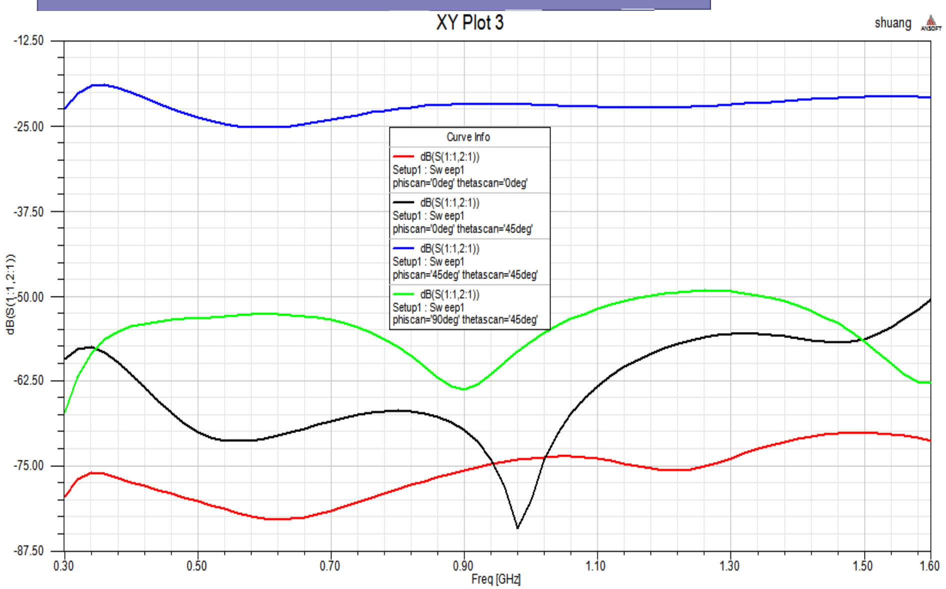
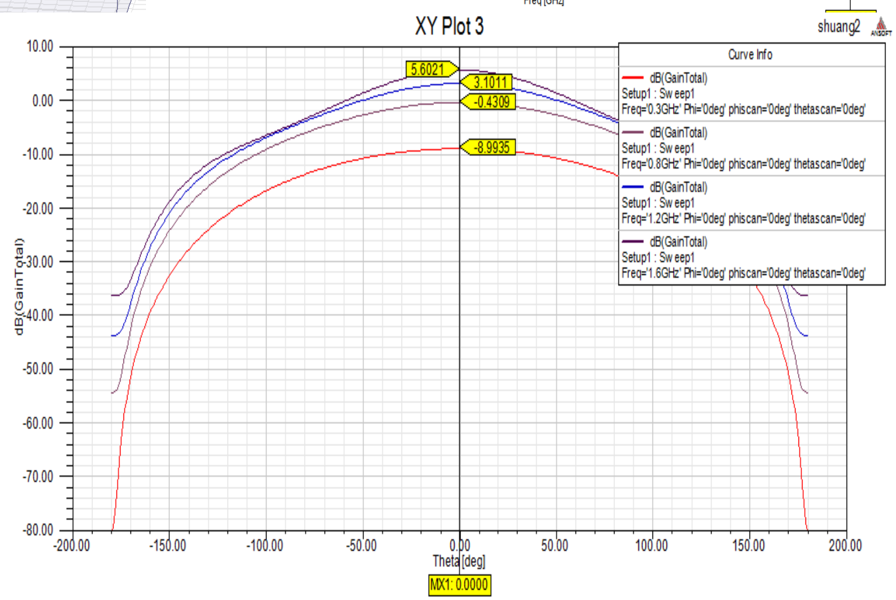
Antenna Array with feeding method 1











Microstrip ROGERS RO4003C

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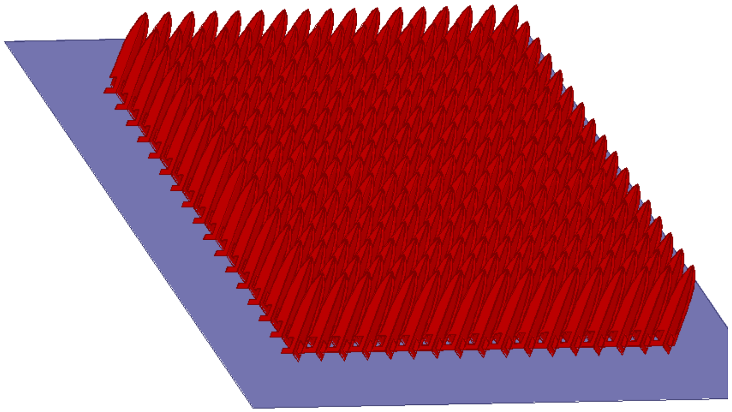
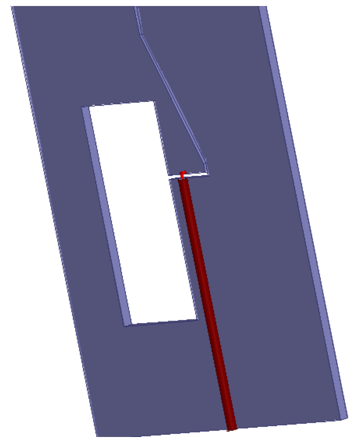
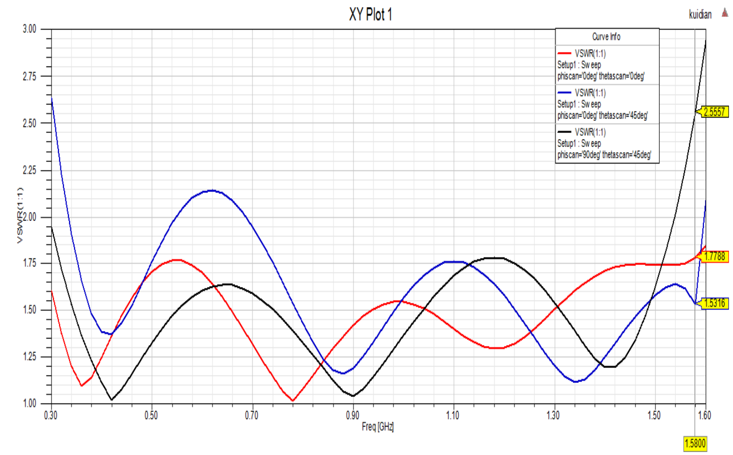
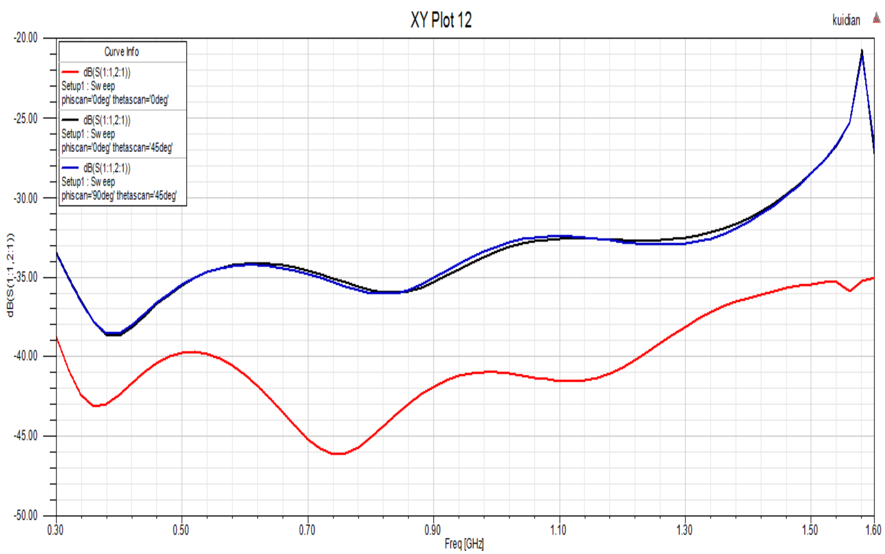
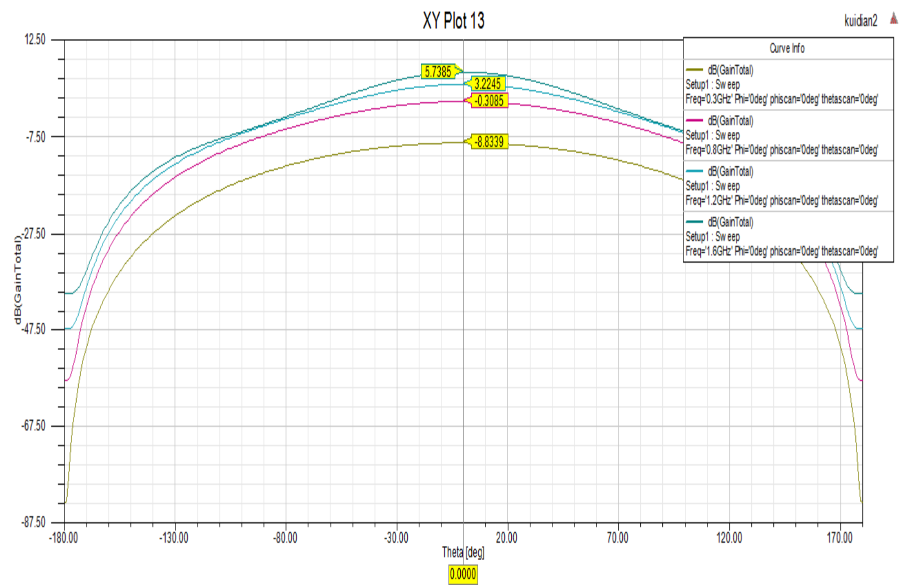
Antenna Array with feeding method 2











Aluminum conductor

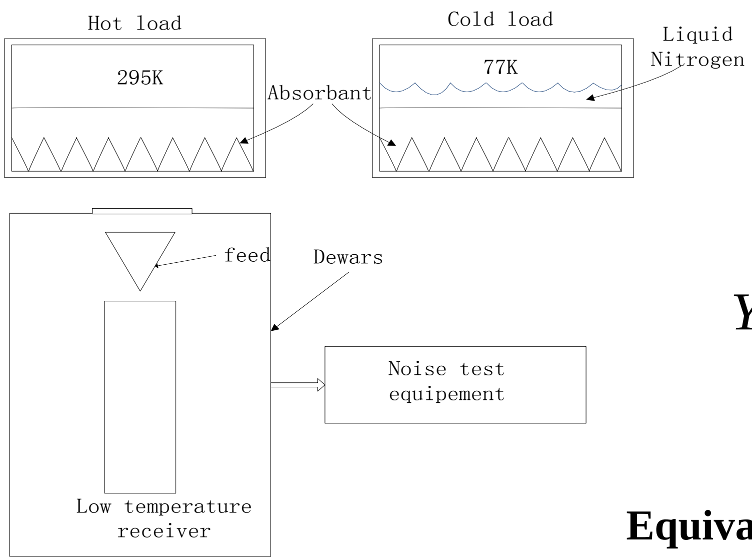
Outline

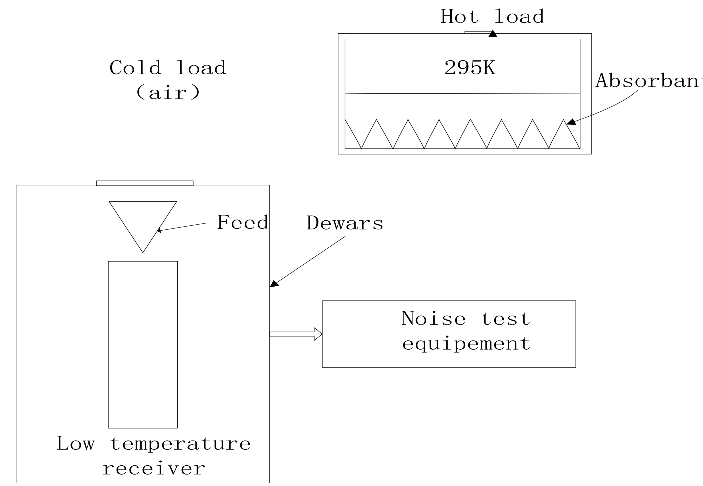
- ◆ Work carried out in KLAASA
- ◆ **Low-temperature-noise test**
- ◆ optical/electric transceiver
- ◆ LNA
- ◆ What to do next

Low-noise-temperature test

Y-factor method

- Sky as cold load or
- Liquid Nitrogen as cold load





$$Y(dB) = P_h(dB) - P_c(dB)$$

$$\Rightarrow Y = 10^{\frac{Y(dB)}{10}}$$

Equivalent noise temperature of low-temperature receiver (feed included)

$$\Rightarrow T_{e1} = \frac{T_h - YT_c}{T - 1}$$

With T_h (K) temperature of hot load
T_c (K) temperature of cold load (liquid Nitrogen 77K, cold sky 6K)

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Low-noise-temperature test

An example

Table1 Test data with liquid Nitrogen as cold load(T_c=77 K)

Freq.（GHz）	1	2	3	4	5	6	7	8	9
Hot power (dBm)	19.605	18.257	18.142	20.241	18.382	18.262	17.512	17	17.23
Cold power (dBm)	15.251	13.897	13.666	15.665	13.887	13.696	13.166	12.685	12.851
Y-factor (dB)	4.354	4.36	4.476	4.576	4.495	4.566	4.346	4.315	4.379
Noise Temperature（K）	40.66	40.41	35.59	31.66	34.83	32.04	41.00	42.35	43.

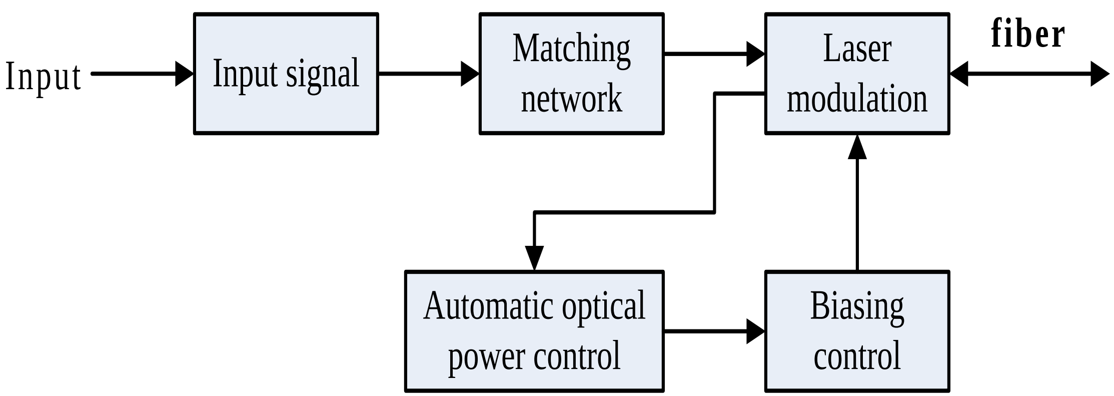
Table2 Test data with cold air as cold load(T_c=6 K)

Freq.（GHz）	1	2	3	4	5	6	7	8	9
Hot power (dBm)	19.7125	18.354	18.251	20.341	18.465	18.371	17.621	17.105	17.
Cold power (dBm)	11.4785	10.116	9.371	11.191	9.575	9.401	9.271	8.965	9.29
Y-factor (dB)	8.234	8.238	8.88	9.15	8.89	8.97	8.35	8.14	8.05
Noise Temperature（K）	42.367	42.36	34.7	31.96	34.67	33.77	40.9	43.67	44.9

Outline

- Work carried out in KLAASA
- Low-temperature-noise test
- optical/electric transceiver
- LNA
- What to do next

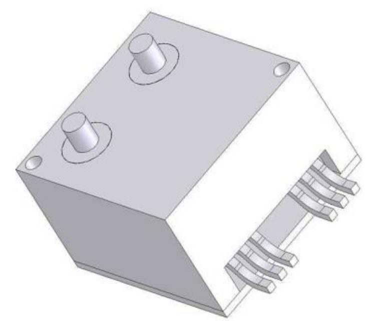
Initial o/e transceiver for LFAA



TX

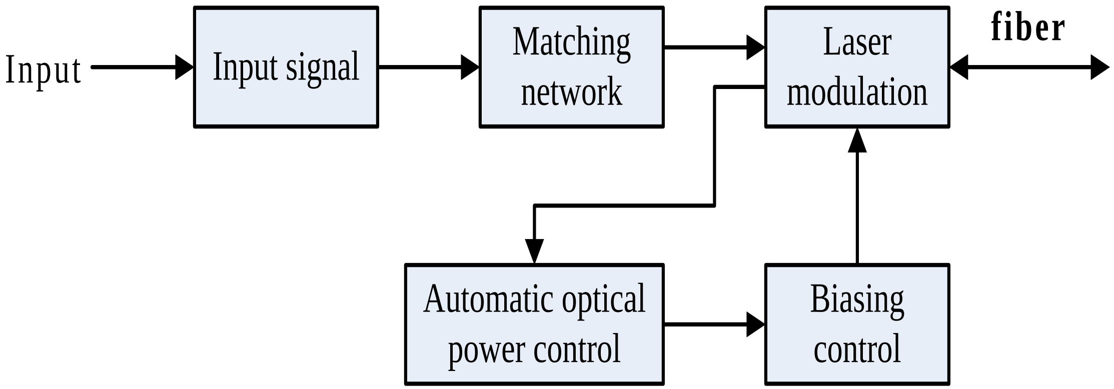
Voltage supply=5 V, $I_{modulation}$ + $I_{biasing}$=20 mA
→ Power laser driver= 100 mW

Frequency：**50～675MHz；**
RF input：**-45～-5dBm；**
Insertion loss：＜ **25dB；**
VSWR：＜ **2.0；**
Wavelength：**1550nm；**
Output power：＞ **-8dBm；**
Temperature：**-40～55℃；**

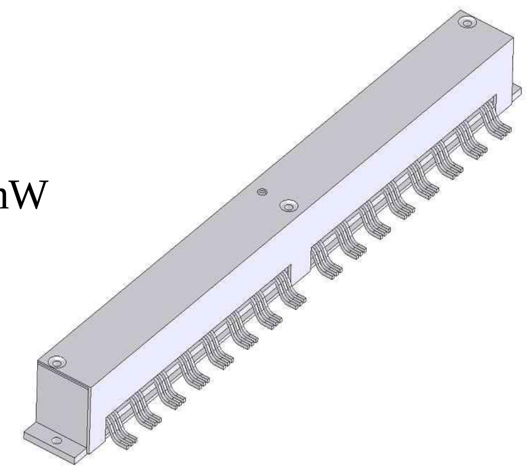


Volume： 24×24×8mm^3

Initial o/e transceiver for LFAA



RX



Maximum $I_{collector}$ < 20 mA, power consumption of RX < 100 mW

Frequency：**50～675MHz；**
Insertion loss：**＜ 25dB；**
VSWR：**＜ 2.0；**
Wavelength：**1550nm；**
Temperature：**-40～55℃；**

Volume： $190\times20\times10\text{mm}^3$

Outline

- Work carried out in KLAASA
- Low-temperature-noise test
- o/e receivers
- **LNA design**
- What to do next

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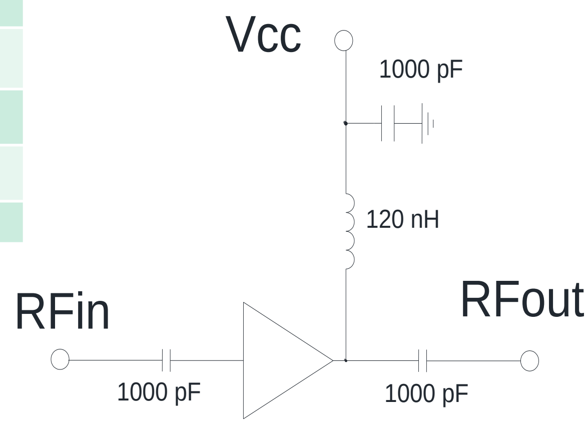
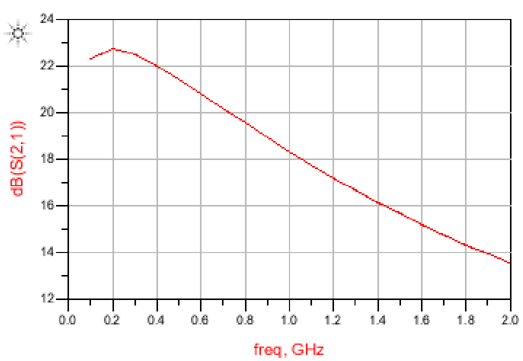
LNA

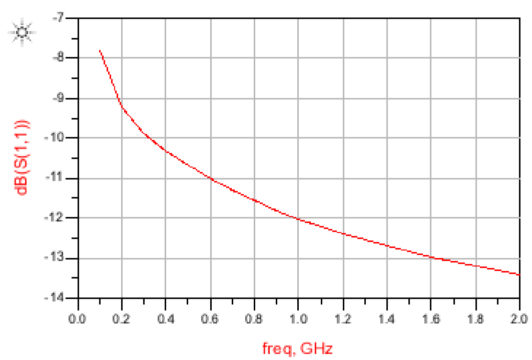
Electrical performance (V_{CC}=3.3 V, I_{CC}=40 mA)

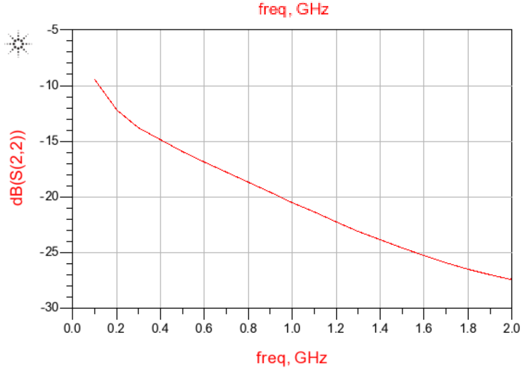
Parameter	Freq. (GHz)	Min.	typical	Max.
Gain (dB)	0.4-1.6	15	20	23
Input/output return loss (dB)	0.4-1.6		10	
Reverse isolation (dB)	0.4-1.6	20	24	28
P_{1dB} (dBm)	0.4-1.6 (T_A=25° C)		8	
OIP_3 (dBm)	0.4-1.6 (T_A=25° C)			
NF (dB)	0.4-1.6 (T_A=25° C)	0.49	0.52	0.56
Icc (mA)			40	

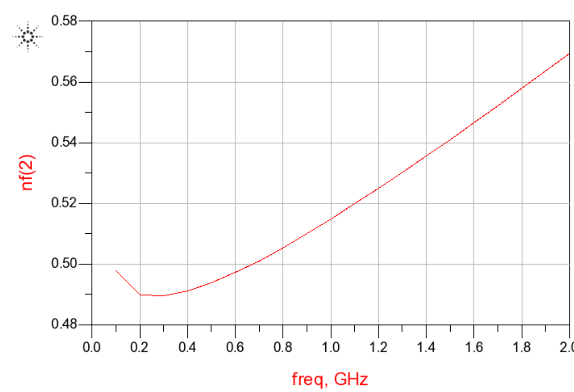
Single ended











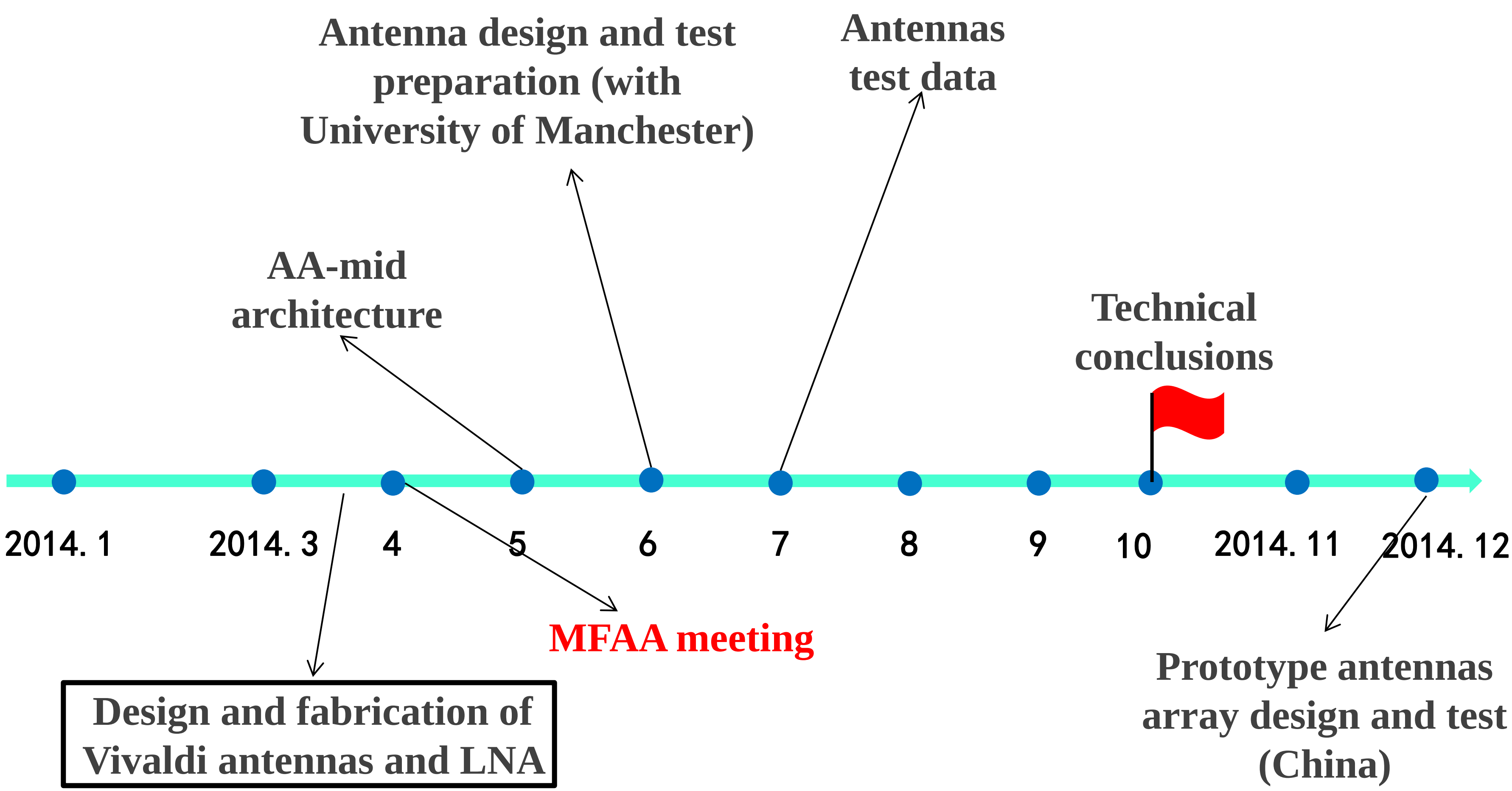
Outline

- Work carried out in KLAASA
- Low-temperature-noise test
- o/e receivers
- Differential LNA
- What to do next

博微 中国电子科技集团公司 第三十八研究所

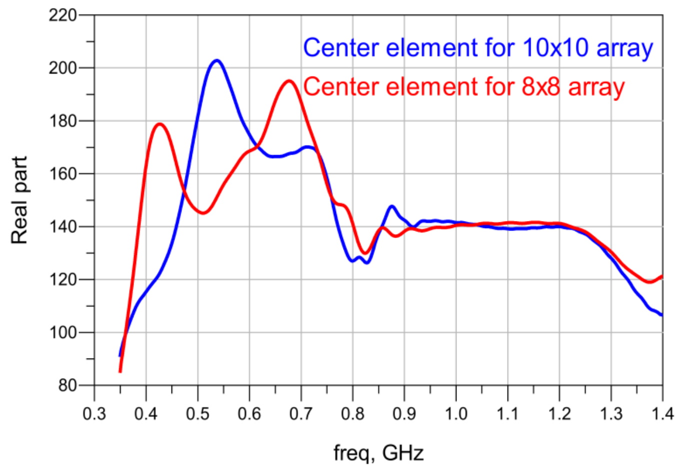
Work in 2014

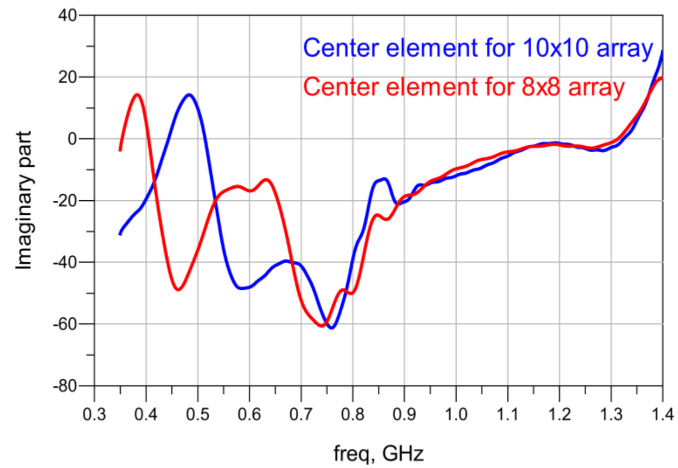
■ Schedule for AA-mid



Obs. de Paris, Nancay

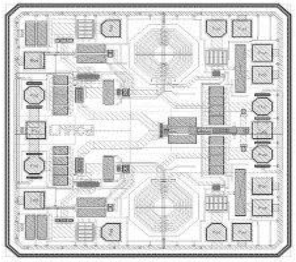
LNA for ORA

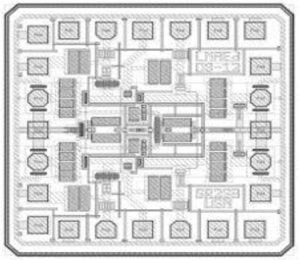




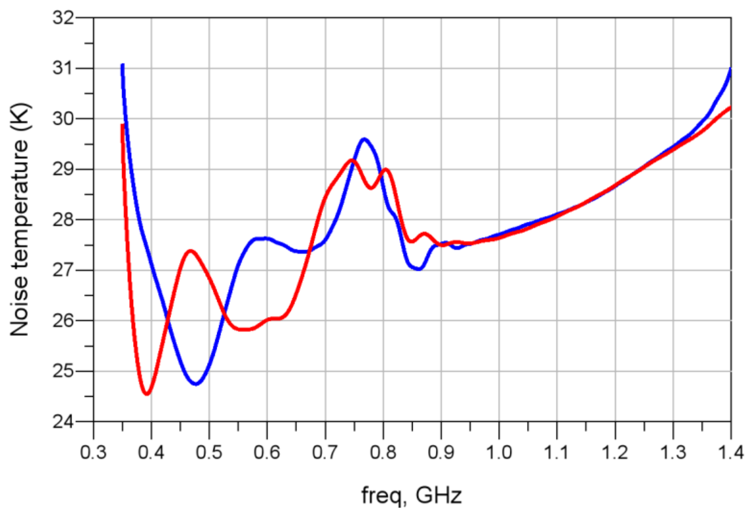
Antenna impedance given by Manchester

- **LNA design with NXP QUBIC4Xi Process technology**
- **Two topologies used in differential configuration:**
  - **LNAEd: two common emitter topology**
  - **LNACd: cascode topology**
- **Simulation based on a measured active impedance as source of the LNA**
- **DC power = 3.3V**
- **LNA in QFN package.**



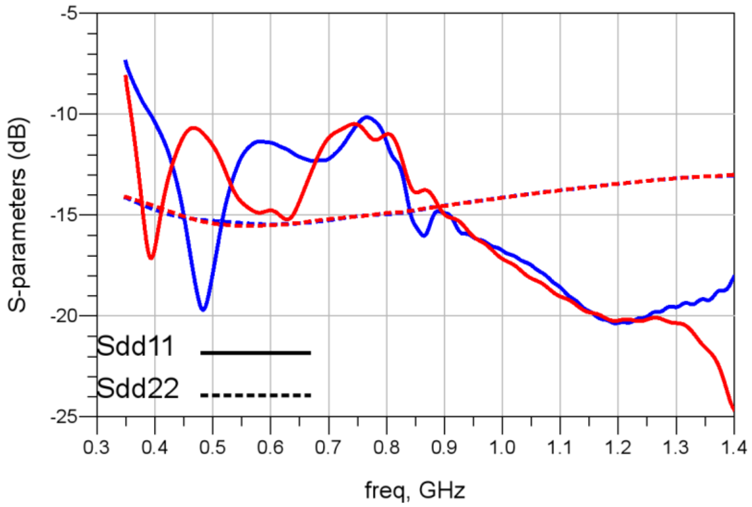


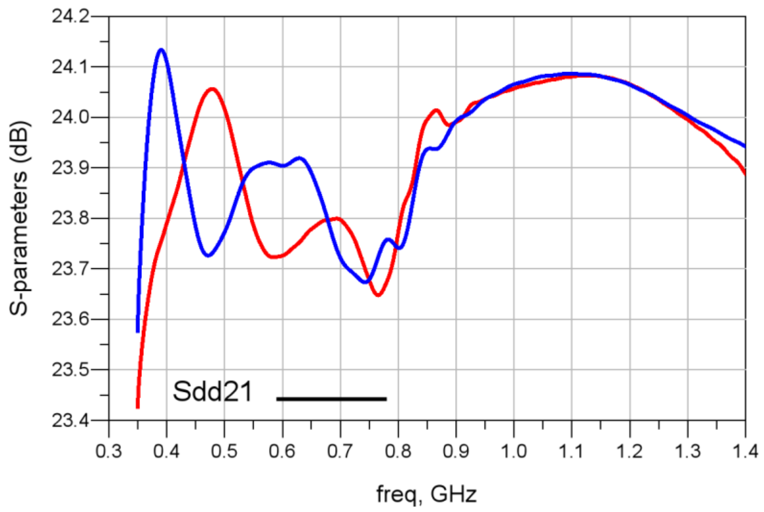
LNA for ORA : LNACd



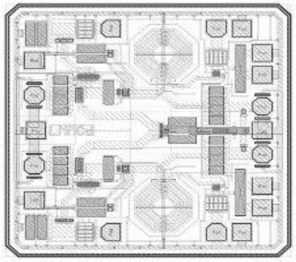
Center element for 10x10 array

Center element for 8x8 array

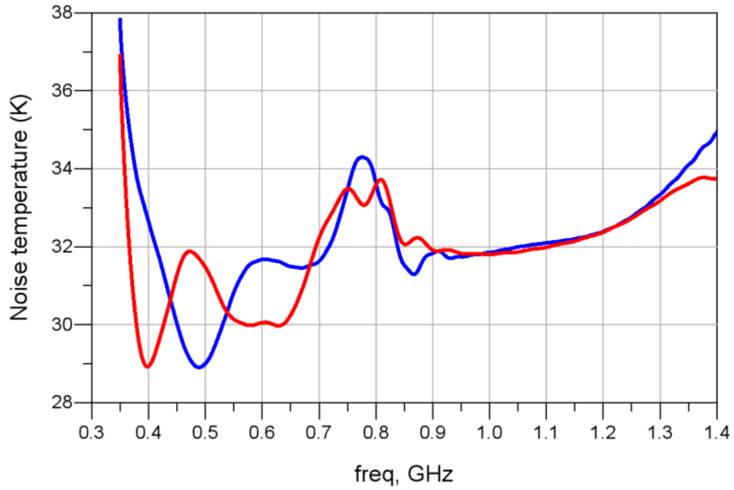




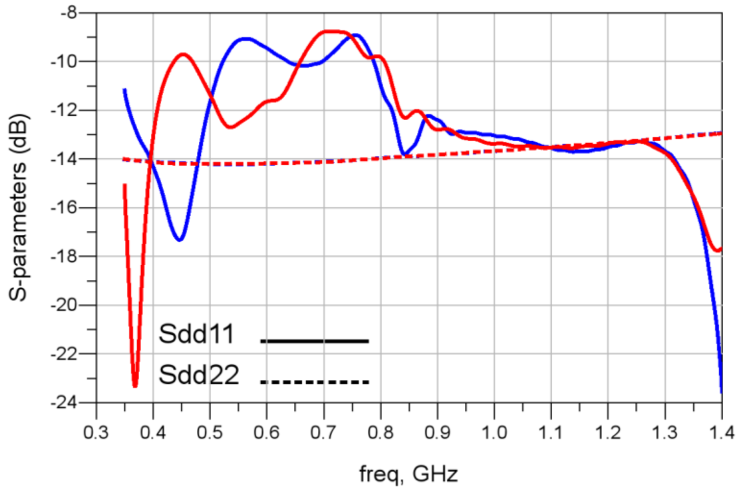
LNA simulation with a measured active input impedance for the centre element as the source impedance for the LNA. The topology used is a cascode in differential configuration.

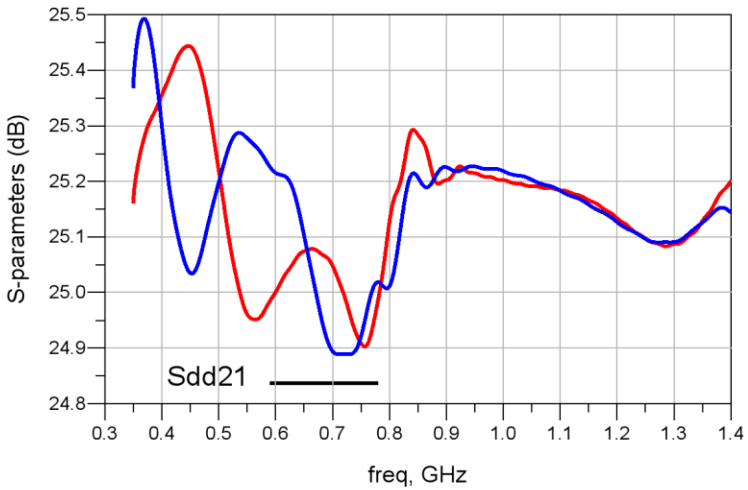


LNA for ORA : LNAEd

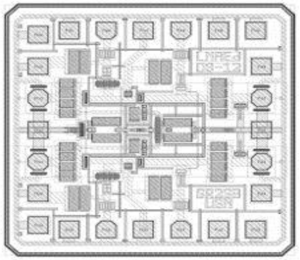


Center element for 10x10 array
Center element for 8x8 array





LNA simulation with a measured active input impedance for the center element as the source impedance for the LNA. The topology used is a two common-emitter in differential configuration.



AAMID 2014

The next step in SKA Technology

April 2nd, 2014
ASTRON, Dwingeloo

Logarithmically Periodic Dipole Antenna for the SKA Mid-Frequency Aperture Array

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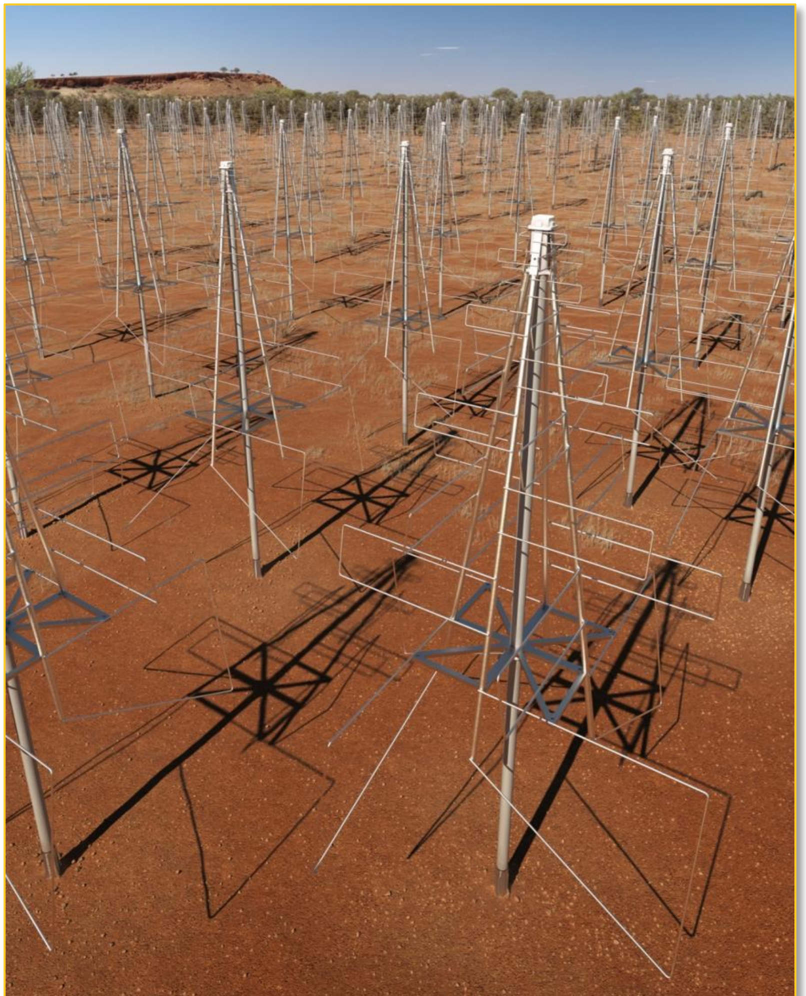
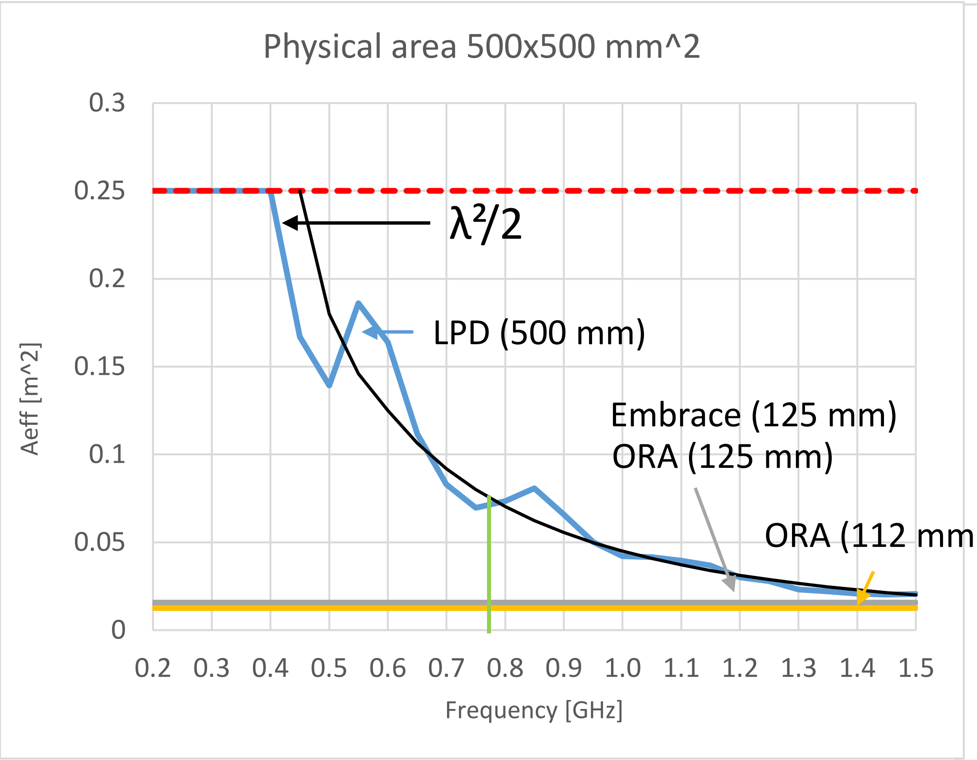
LFAA array requirements

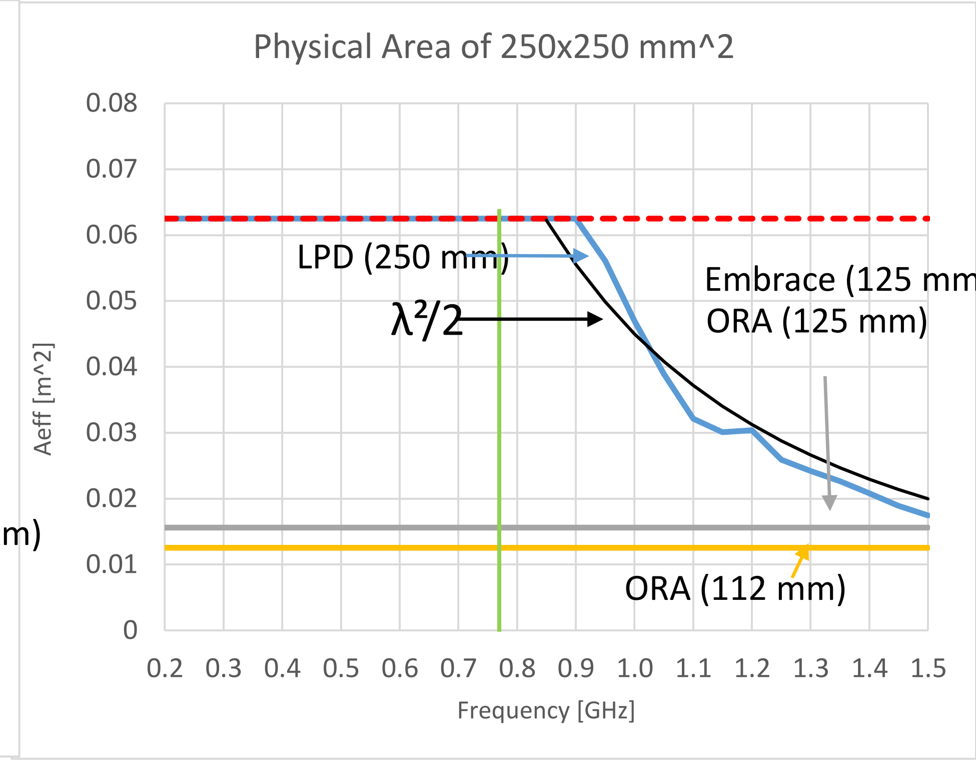


Array antenna requirements

Antenna type: LPD (SKALA)
Frequency: 50MHz – 350MHz (& up to 650MHz)
Antennas: 2^{18}
Station size: (35m) 256 antennas
Sensitivity : ~1000m^2/K (110–350MHz)
Polarisation: Dual (IXR>15dB)
Scan angle: 45°max.

Introduction



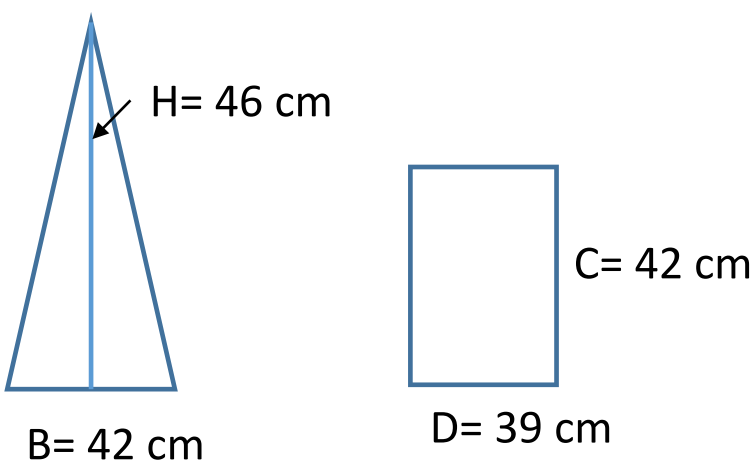


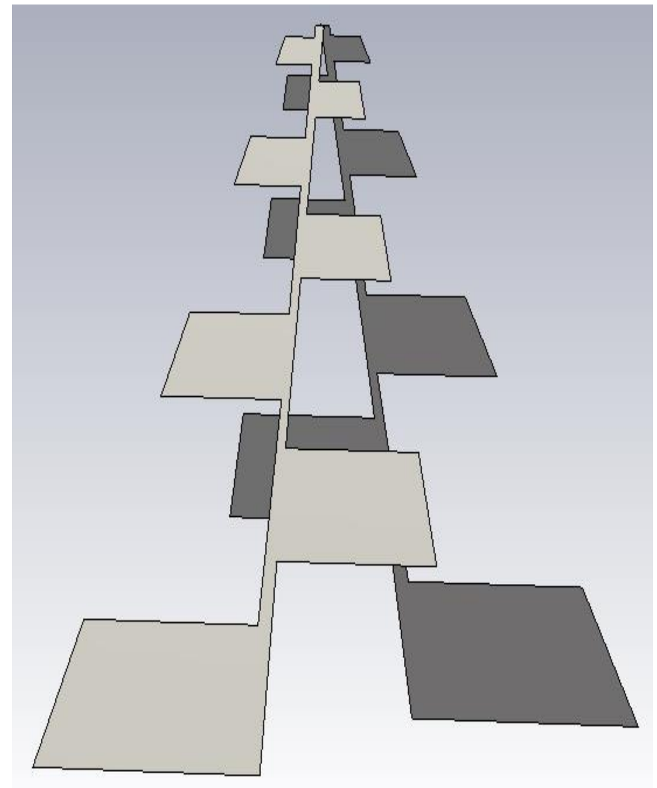
According to White paper SKADS 2009
Sensitivity = 10,000 m²/K @ 800 MHz
Tsys = 60 K is assumed

Embrace/ORA125mm need
38,400,000 cells
LPD needs 8,156,939 antennas
(cells)
4 to 5 times less elements

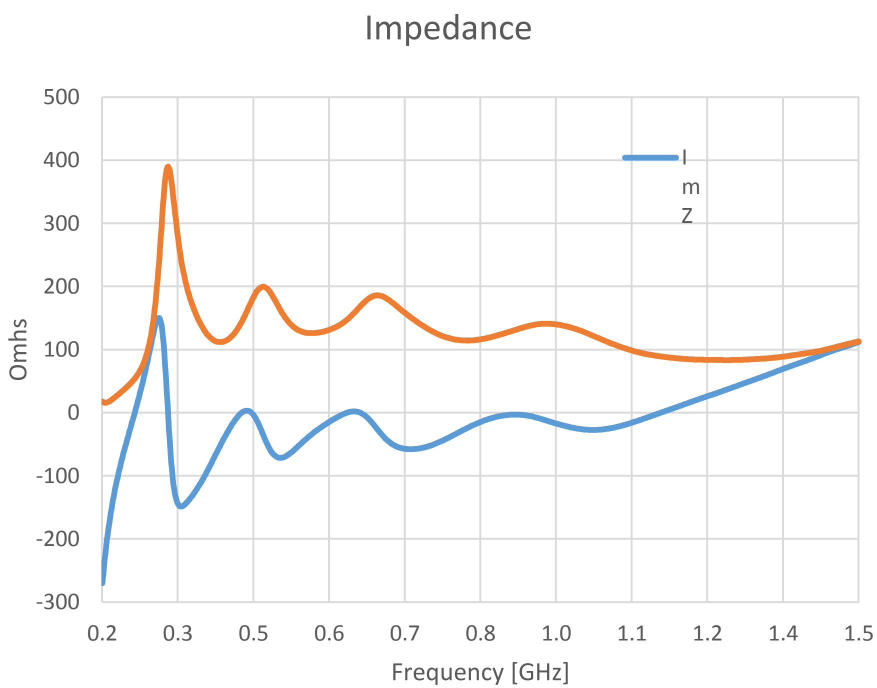
Log-Periodic Mid-Frequency design (one polarization)

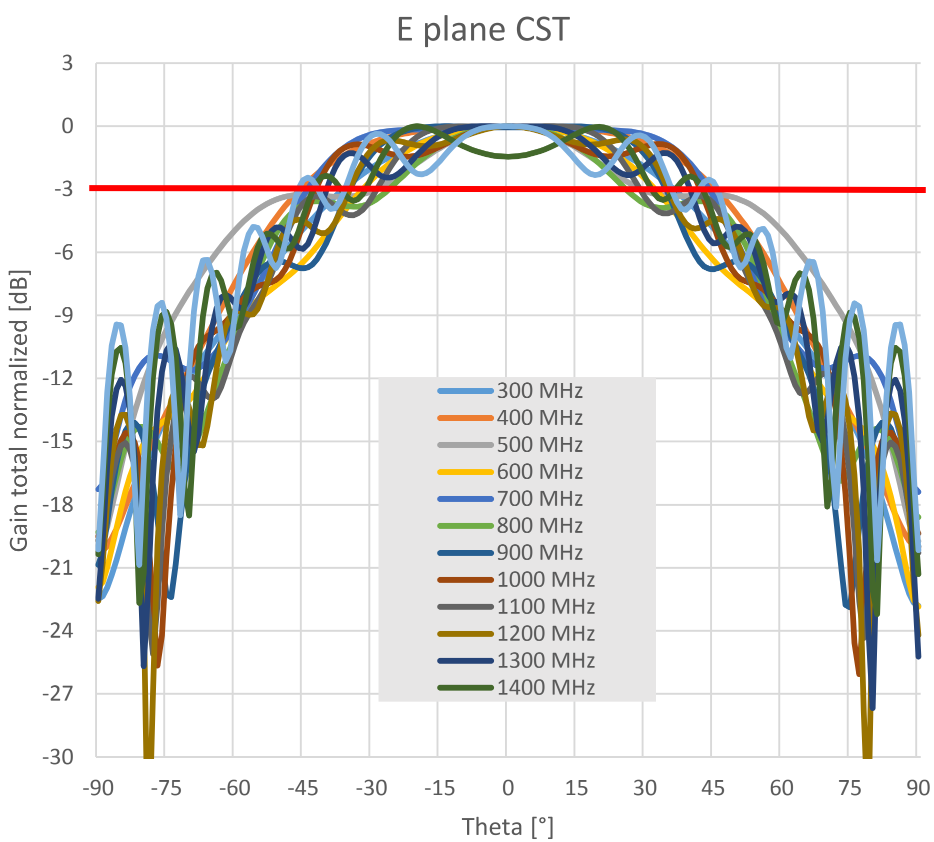
Parameter	Goal
Bandwidth	0.3 – 1.45 GHz FBW(131%) ~ 5:1
FoV (Beamwidth)	+/- 45°
System Noise	≤ 35 K
Polarization	2 linear
Impedance	~ 100 Ω



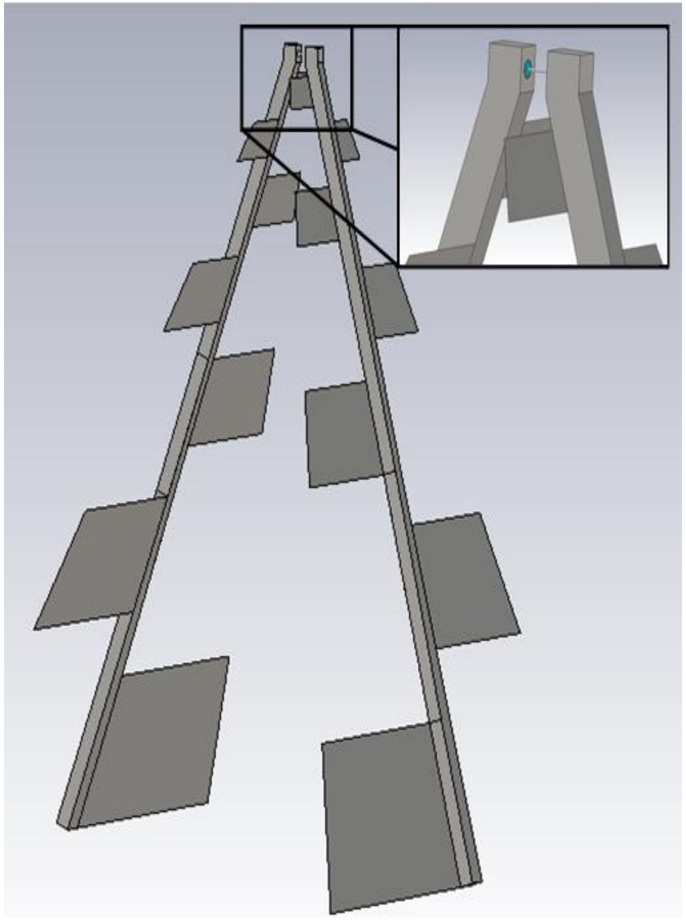


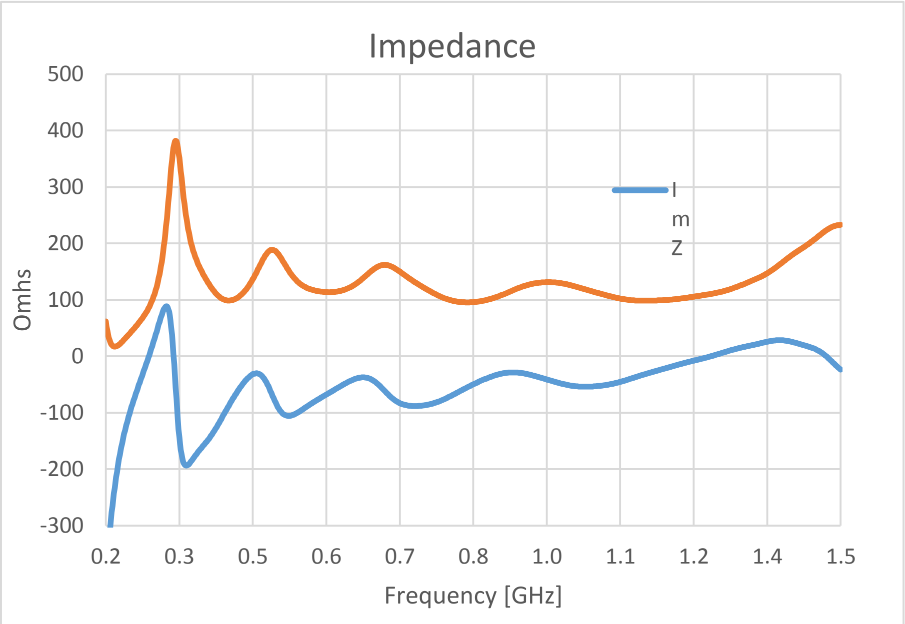
LPMF simulated results

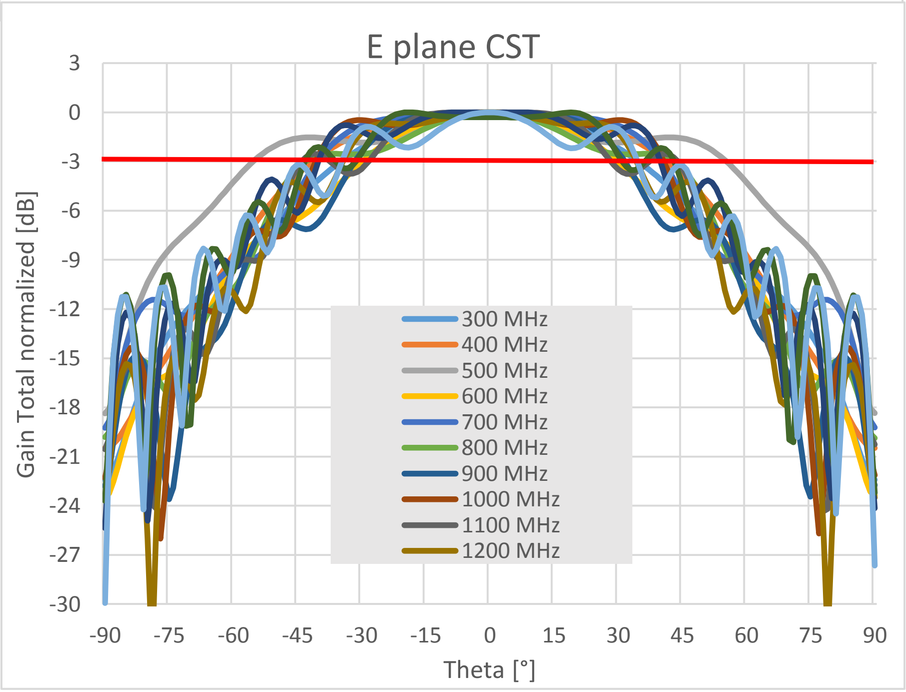




Unbalanced feeding

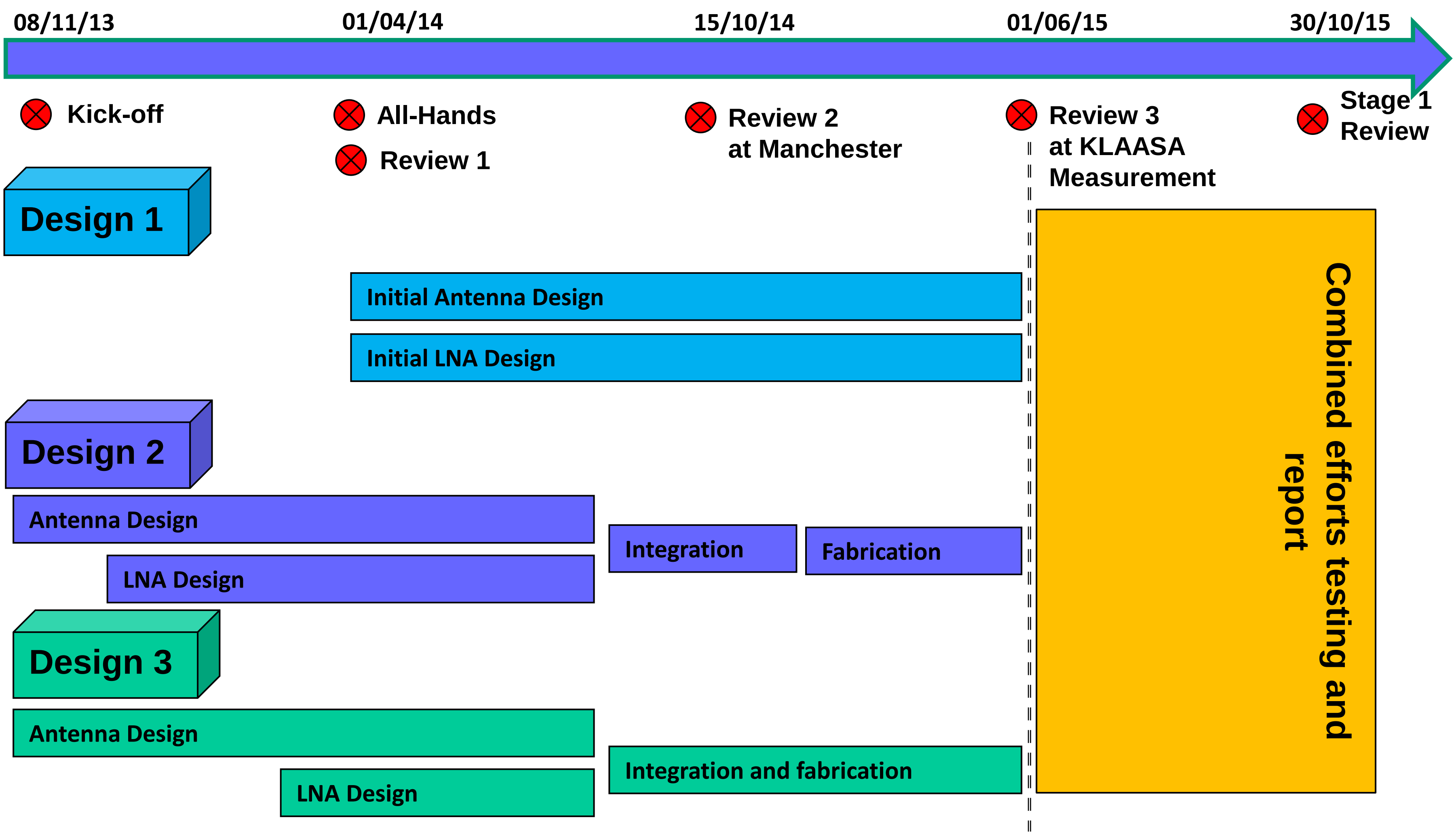




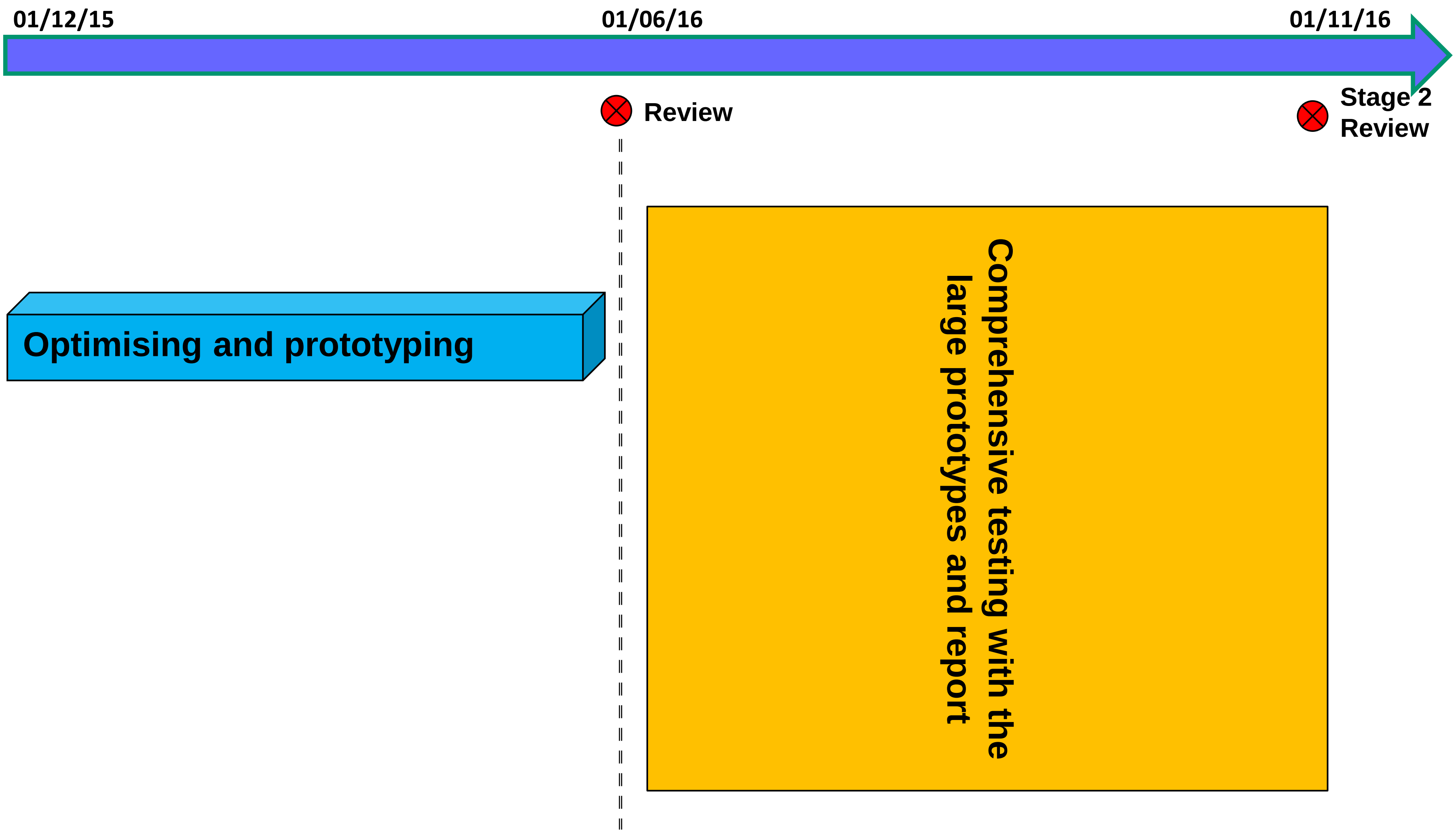


The Forward Planning

Front-End Timeline Stage 1



Project Timeline Stage 2



Highlights of the milestones

- A measurement document will be produced to describe the detailed measurement items for Front-End study as soon as the requirement specification for AAMID becomes available
- A research Front-End prototype panel from each design to be ready by June 2015, combined efforts to make measurements in the stage 1
- Larger prototype arrays are planned for the stage 2 study, comprehensive on-site measurements is planned

The Closer Collaboration Regime

The stronger link

- There is a need to build a stronger link to deliver. There will be three key reviews in stage 1 initially on 01/04/14, 15/10/14 and 01/06/15, but a regular meeting will be arranged.
- Manchester will invite one or two engineers from KLAASA to Manchester to collaborate on design 2 and design 3 (and once a month tele-conf).
- Regular communication(Bi-weekly tele-conf) between Manchester and Nancay will be established.

if SKA == MFAA

then

MFAA = AAMID Front-Ends

Thank you