

# SKA-based receivers for eMerlin

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UK SKA development funding for:

- Cryogenic receivers for SKA-Mid
- Low-power cryogenics
- Digital data acquisition and signal processing for SKA-Low

...and many other things

This boost for technology development in UK provides opportunity for eMerlin upgrades & development:

- SKA-compatible hardware
- Highest-performance systems available
- Maintains UK technical lead

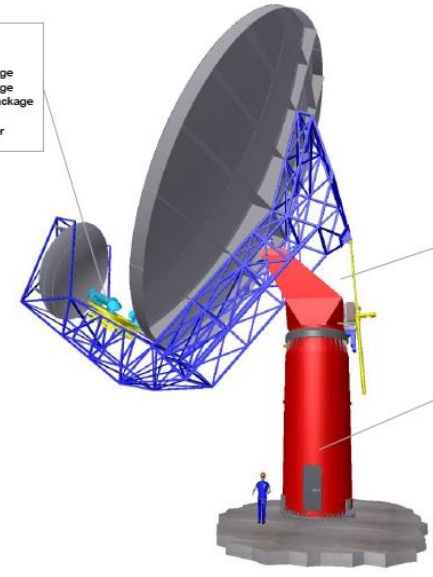
SKA-Mid in 5(ish) bands in 3 packages:

Band 1: 350 – 1050 MHz  
(Chalmers)

Band 2: 950 – 1750 MHz  
(EMSS)

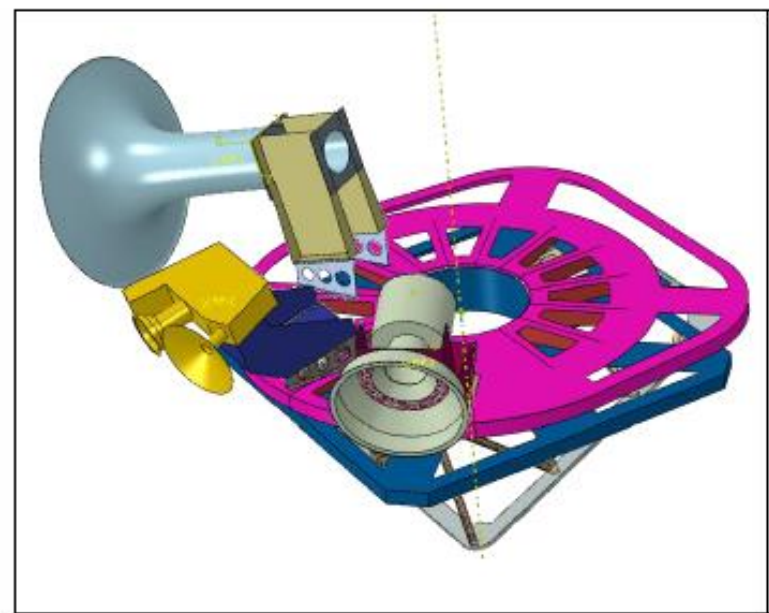
Band 3,4,5: 1.65 – 3 GHz  
3 – 5.2 GHz  
4.6 – 13.8 GHz  
(Oxford)

- Indexer with:
- Single Pixel Feeds:
  - Band 1 feed package
  - Band 2 feed package
  - Band 3,4,5 feed package
  - Vacuum Pump
  - RF → RFOF converter

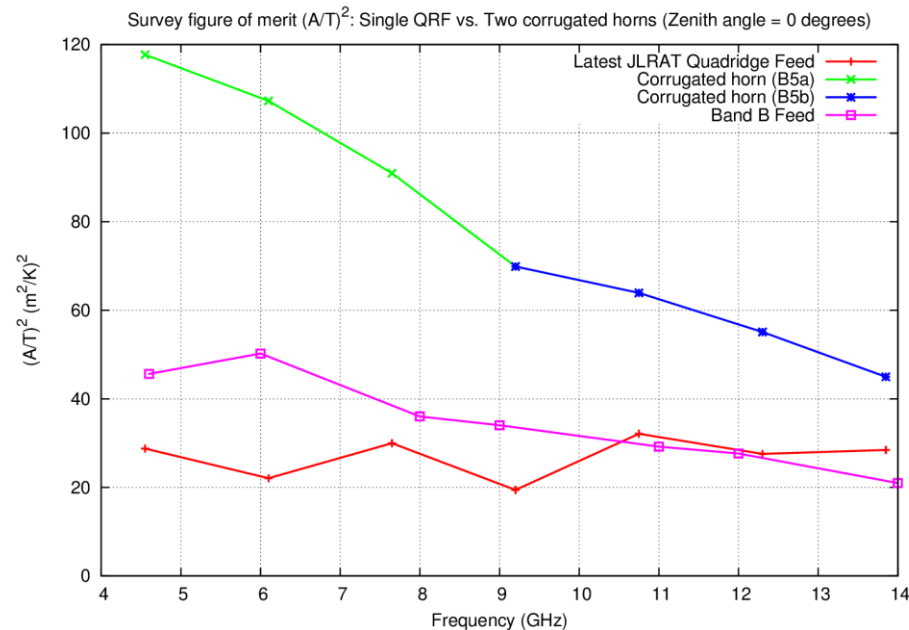
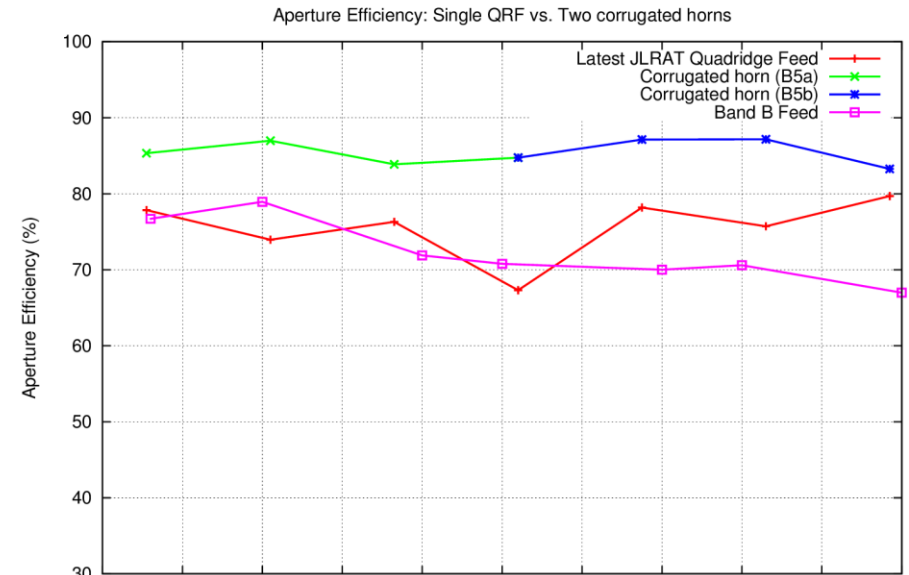
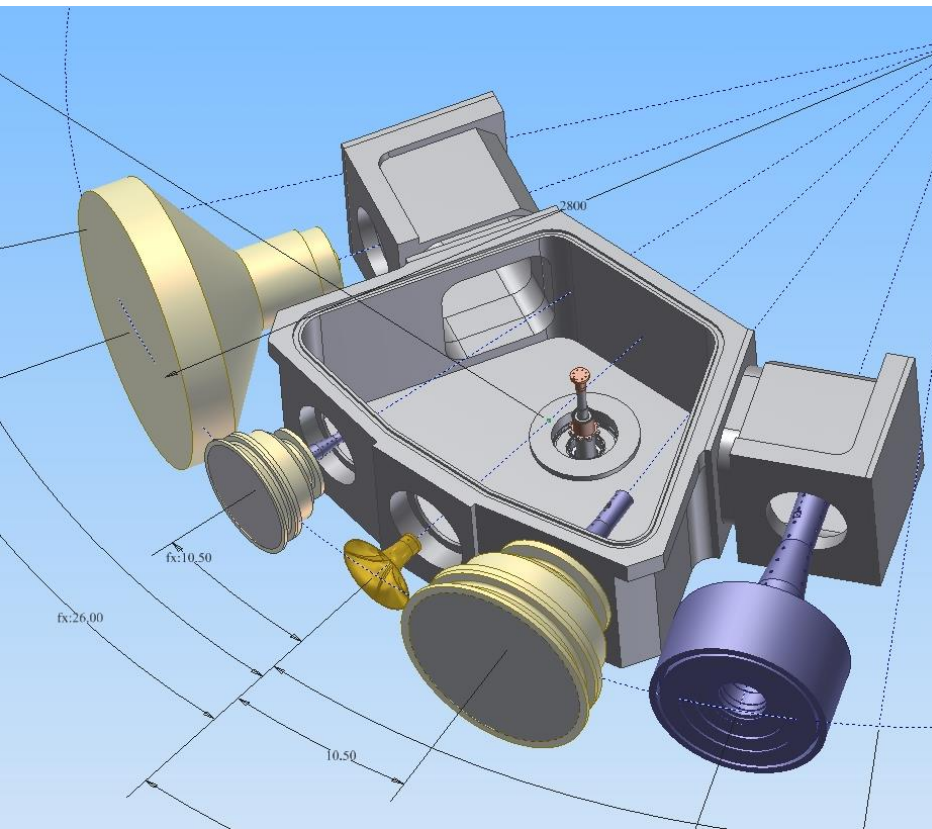


- Helium Compressor  
Helium Bottle

- Shielded compartment with:
- Dish motion controller
  - Receiver components:
  - RFOF receivers
  - Digitisers Band 1-5
  - Time & frequency reference
  - Packetiser
  - SPF Feed controller
  - Local Monitoring and Control
  - SaDT equipment

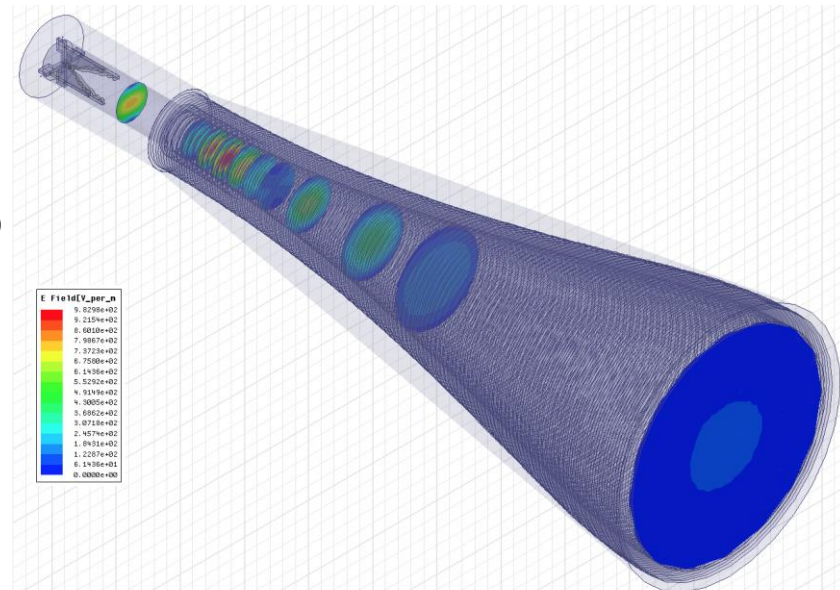


# SKA-Mid Band 5 – design optimisation



Octave bands give much better performance than wide ( $> 2:1$ ) bands  
 Proposing Band 5a, 5b (and potentially 5c) in ~octave bands  
 Multi feeds per cryostat with efficient cryogenics

- Need high-performance feedhorns covering large bandwidth
- Hard to go above 2:1 for low  $f$ -ratio optics
- 2:1 band feeds and LNAs available
  - e.g.
    - 4 – 8 GHz
    - 8 – 16 GHz
- ‘Conventional’ LNAs now at 0.5 K/GHz
- Quantum-limited LNAs now on horizon (superconducting parametric amplifiers)



4 – 8.5 GHz feedhorn/OMT for Goonhilly  
3



6 – 20 GHz LNA (LNF)

Many differences between SKA and eMerlin:

SKA – single optical design, low  $f$ -number (Gregorian), many copies (133 + spares)

eMerlin – many antenna design, high and low  $f$ -numbers (PF and Cassegrain), few copies (7-8)

BUT

SKA means mass production of cryogenic receivers at scale unprecedented in UK – complete refit of eMerlin would be small perturbation on this.

Contiguous coverage from L to K band in  $\sim$ octaves is completely doable.

SKA context:

- eMerlin digitizes 16 RF channels of 500/2000 MHz bandwidth
- SKA-Low will digitize 262,000 RF channels of 500 MHz bandwidth

Solutions for SKA-Low will do eMerlin trivially

- FX correlator scales as  $(N_{\text{ant}} \cdot \log(N_{\text{ch}}) + N_{\text{ant}}^2)B$
- For eMerlin this would be  $O(100 \text{ Gop/s})$
- One SKA-Low processor module has  $O(10,000 \text{ Gop/s})$
- SKA-Low will have  $>8000$  of these...

RF inputs



40G Ethernet  
QSFP+



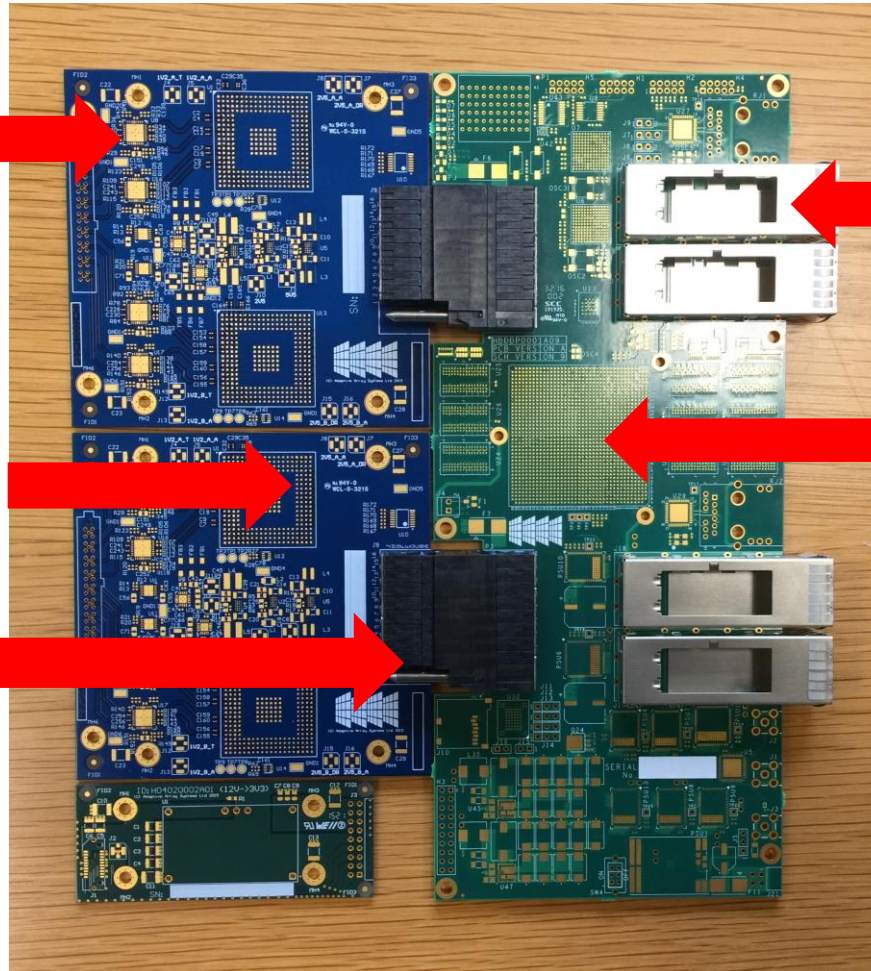
Quad 1.25 GS/s  
14-bit ADCs



Altera Arria  
10/Stratix 10  
FPGA



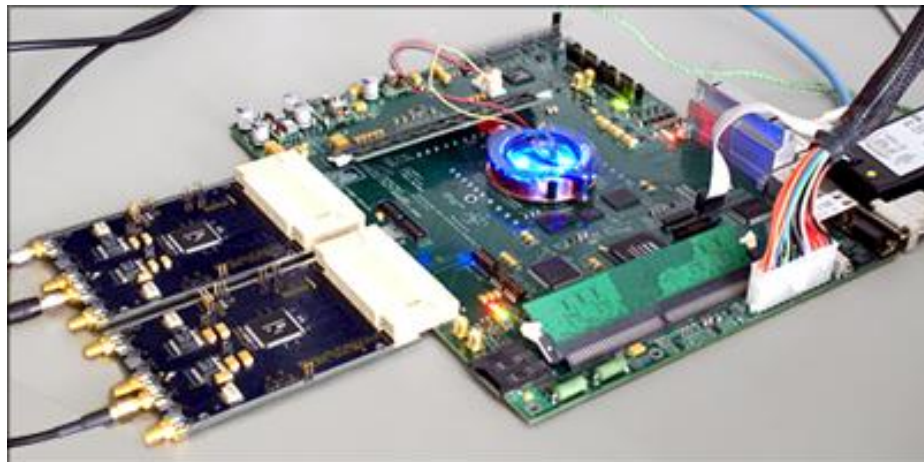
JESD204B  
interface



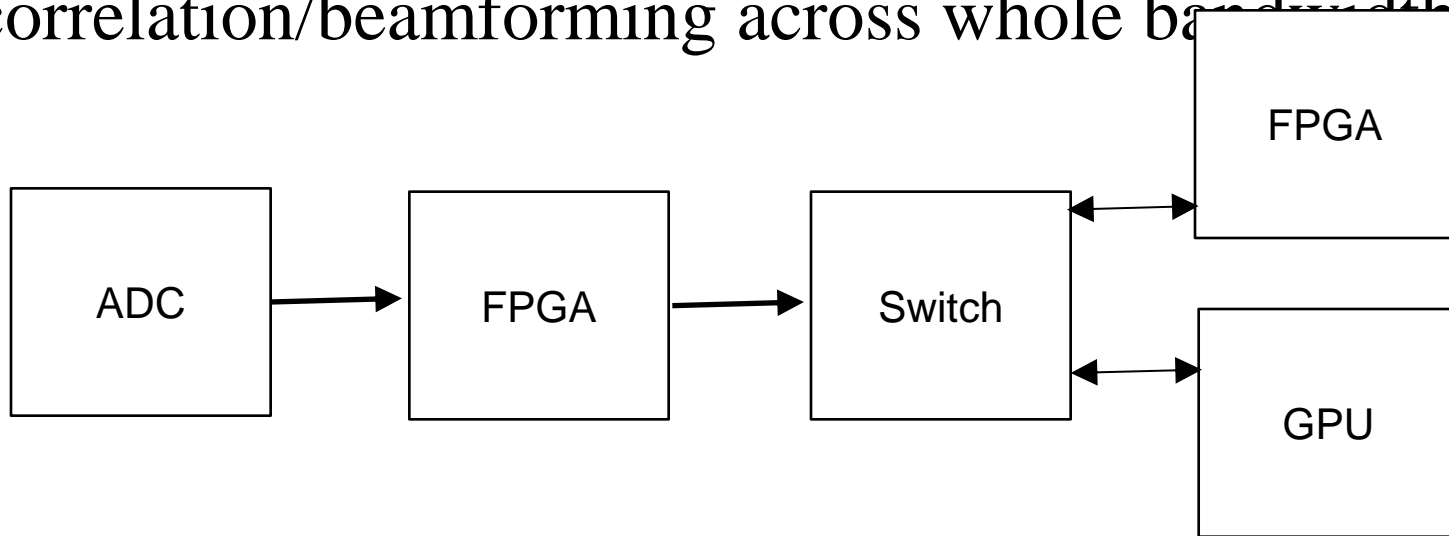
ADC boards interchangeable e.g. 2.5 GS/s 12-bit, 26 GS/s 3.5 bit, also DAC boards



	FPGA	Gop/s	ADC total BW (Gb/s)	RF channels	Freq channels
Roach 1 (CBASS S) (2010)	1 x Xilinx Virtex 5	320	32	4 x 0.5 GHz	64
SKA TPM (2016)	2 x Altera Arria 10	10,000	480	32 x 0.5 GHz	16M
TPM v2 (2018)	2 x Altera Stratix 10	56,000	800	8 x 10 GHz	4096



- Big SKA-led developments in UK in RF, digital hardware, (hopefully) leading to manufacture in UK
- Contiguous coverage from L to K or Ka band with excellent noise performance perfectly possible
- Digital hardware will allow full correlation/beamforming across whole bandwidth:



- All this is a ~small addition to UK SKA1 build phase.

