A Dual Polarised Wideband Planar Phased Array for Radio Astronomy

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Outline

- A brief review of wide-band aperture array antenna design
- AA-mid Antenna design for PrepSKA
- Conclusions and future work

The SKA mid-frequency array

- The requirement is for approaching two octaves of bandwidth (400MHz to 1.4 GHz)
- A scan angle of at least +/-45degs
- Polarimetry is required on the radio astronomical sources so that two orthogonal polarisations are needed

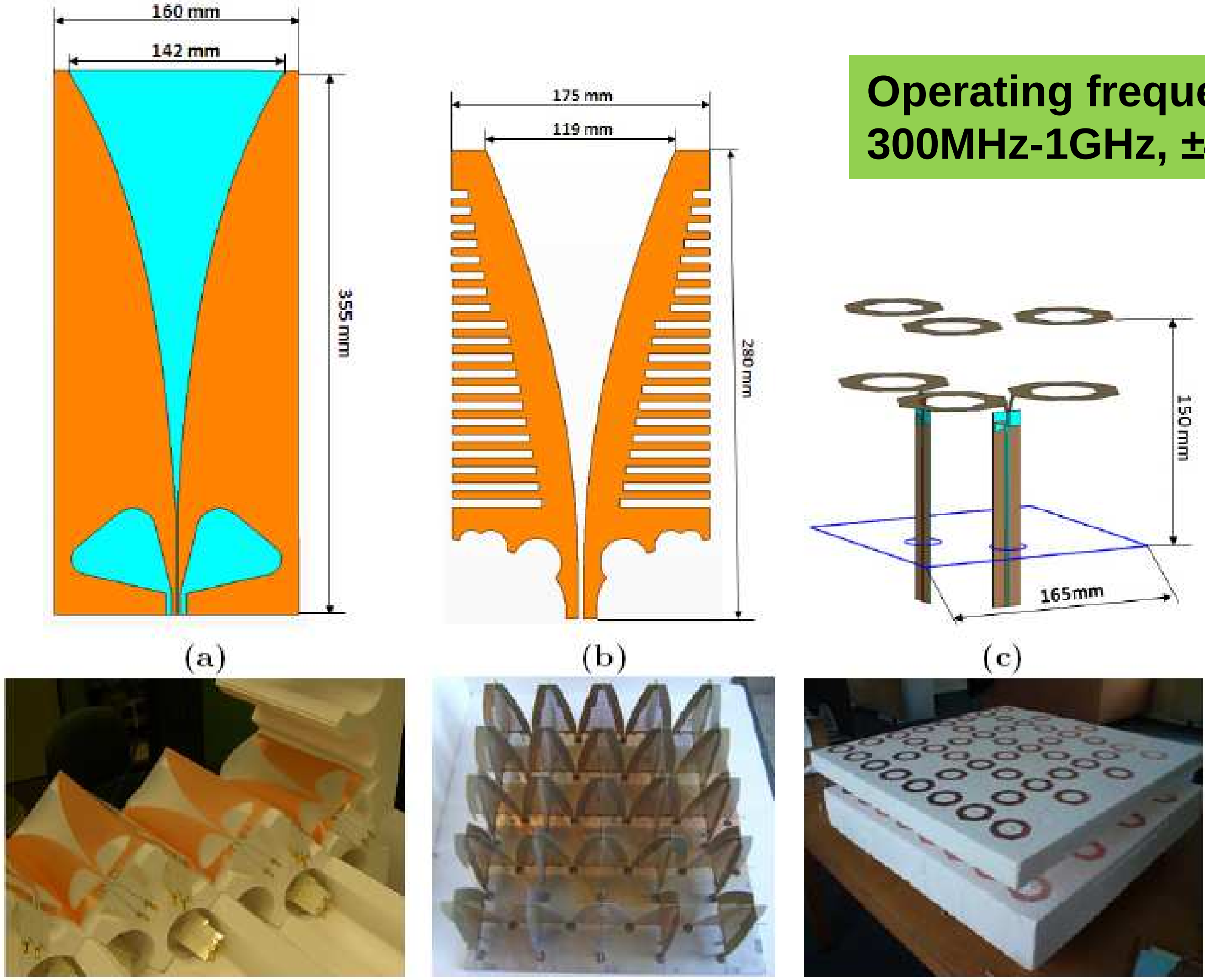
A brief review of wide-band aperture array antenna design

- Three structures have been compared in both theory and in hardware:
  - Vivaldi antenna
    - A structure developed by ASTRON using a thin metallised foil known as FLOTT
  - A modified Bunny Ear antenna incorporating comb line chokes[1]
    - All aluminium laser cut structure
  - A planar antenna using coupled ring radiators termed ORA (Octagonal Ring Antenna,[2])
    - Implemented using polystyrene dielectric and thin copper radiating rings

1. **Y. Zhang, A. K. Brown, "Bunny Ear Combline Antennas for Compact Wide-Band Dual-Polarized Aperture Array," IEEE Transactions on Antennas and Propagation, Vol. 59, No. 8, pp. 3071-3075, August 2011.**
2. **Y. Zhang, A. K. Brown, "Octagonal Ring Antenna for a Compact Dual-Polarized Aperture Array," IEEE Transactions on Antennas and Propagation, Vol. 59, No. 10, pp. 3927-3932, October 2011.**

Aperture Array Antennas

Operating frequency band: 300MHz-1GHz, ±45° scan angle



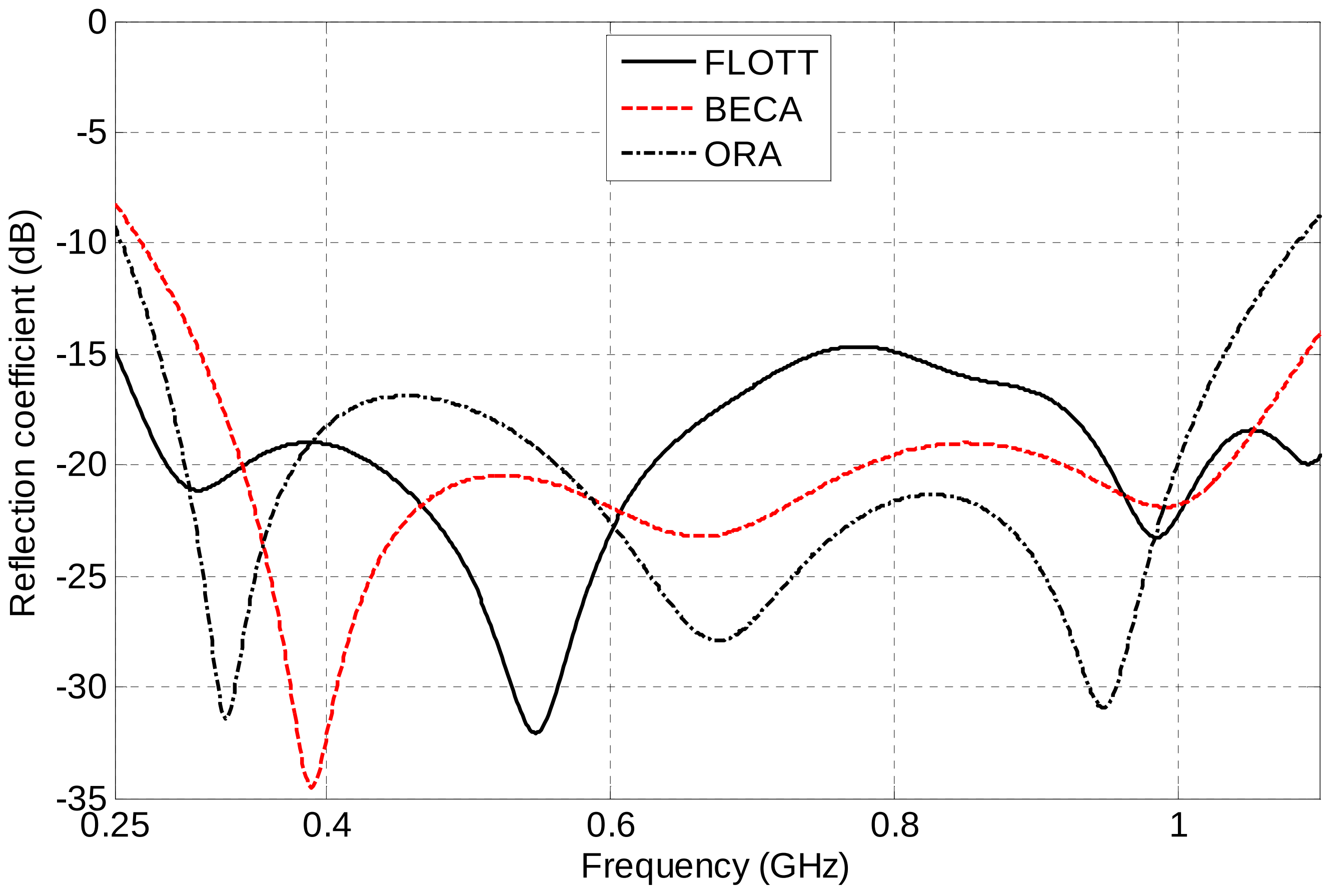
(a) (b) (c) (d) (e) (f)

FLOTT: (a)(d)

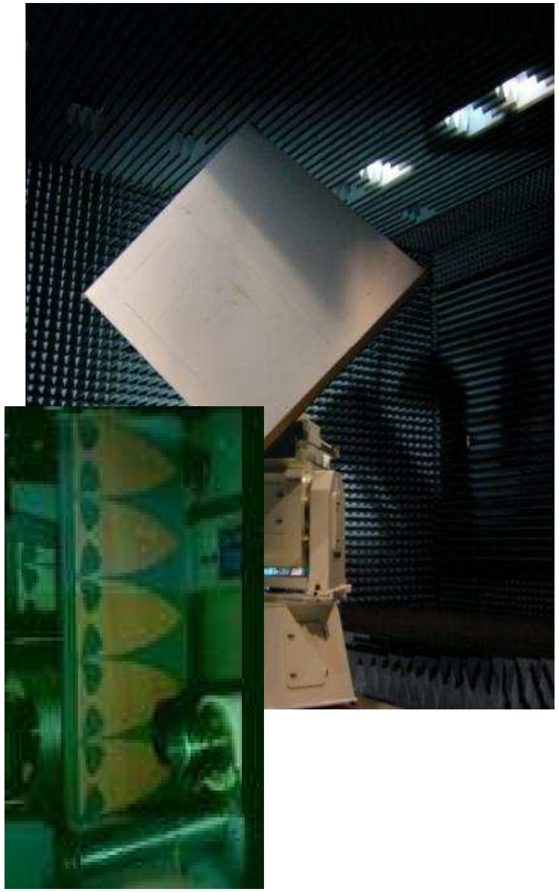
BECA: (b)(e)

ORA: (c)(f)

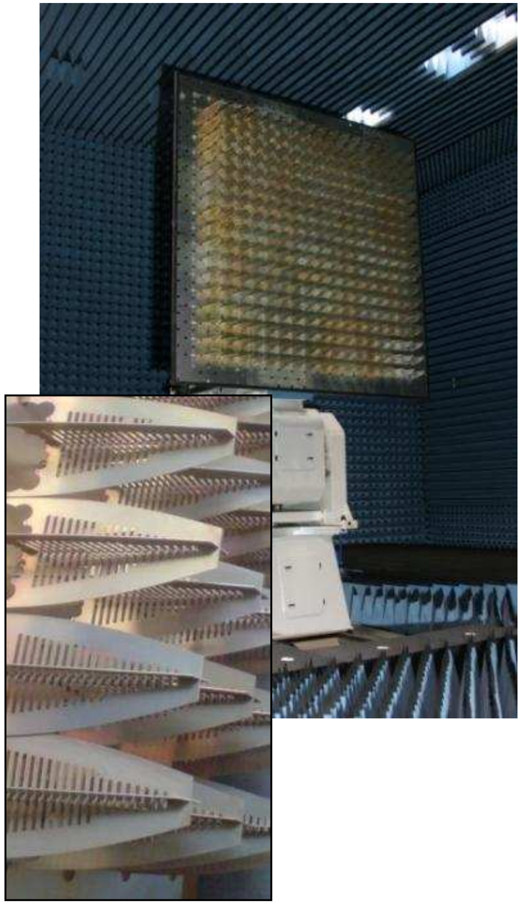
Active reflection coefficient



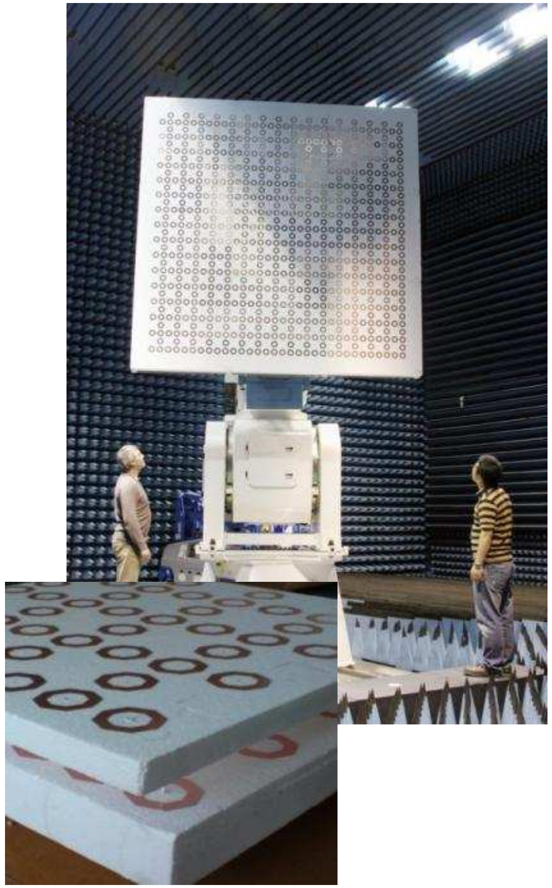
Three candidate designs (16×16 finite arrays)



FLOTT

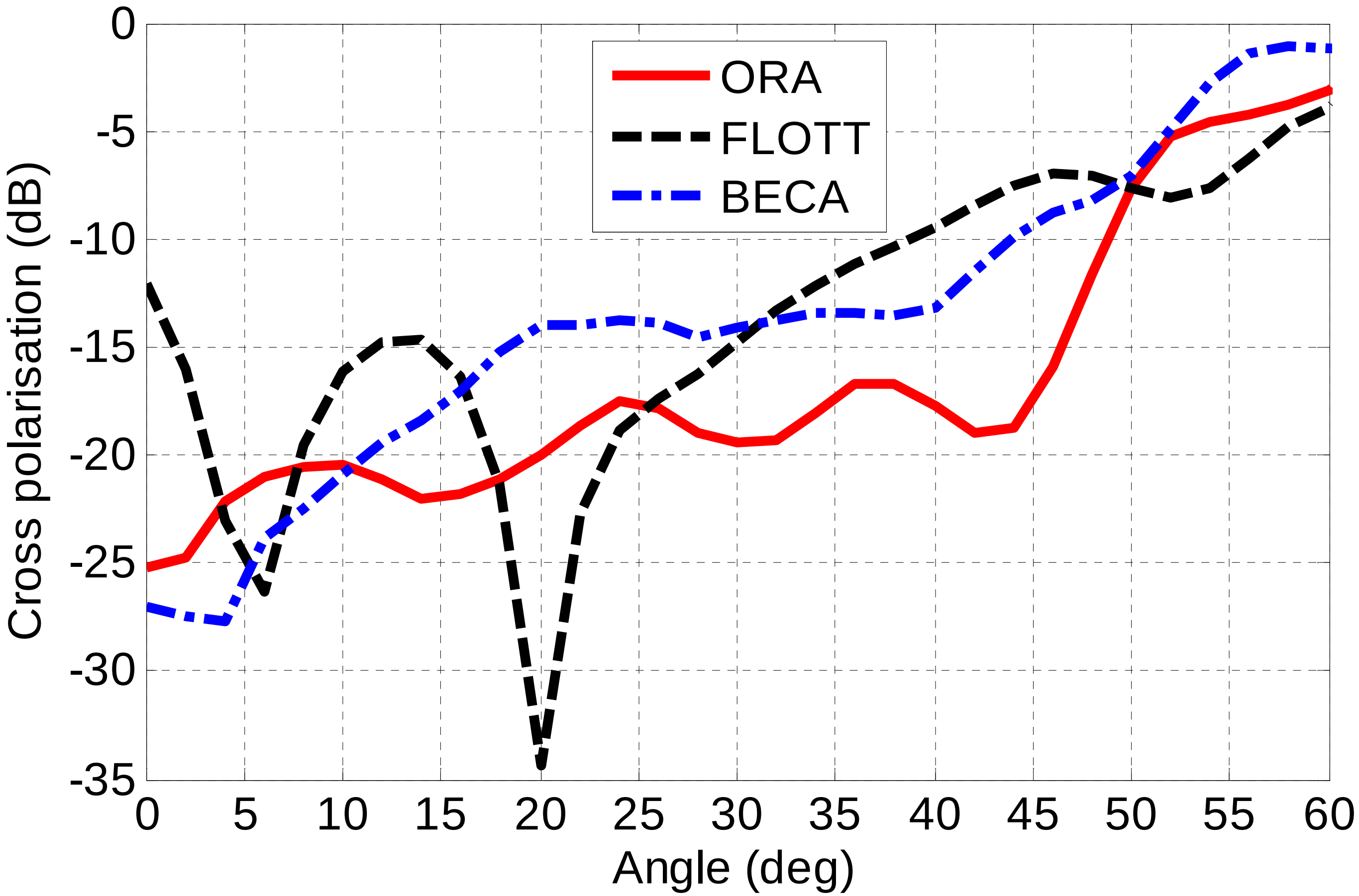


BECA



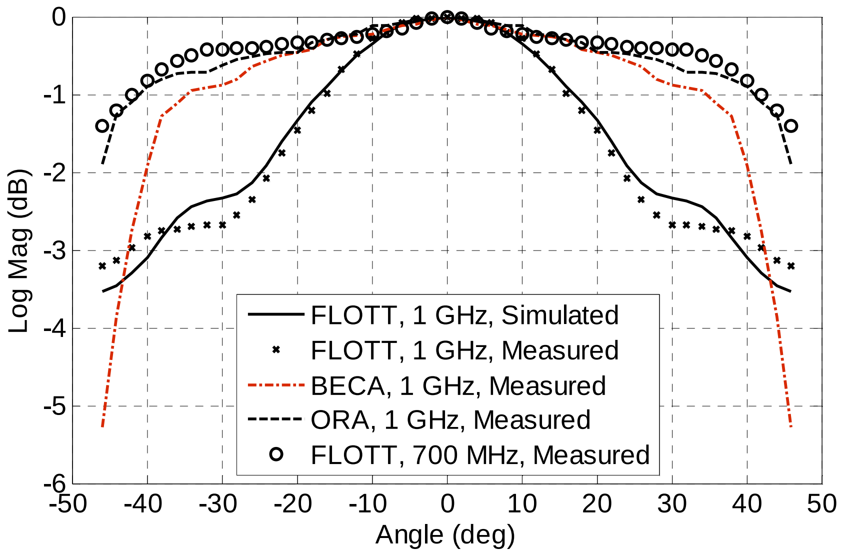
ORA

Cross polarisation in the intercardinal plane at 1 GHz, based on the finite array measurement for the centre element

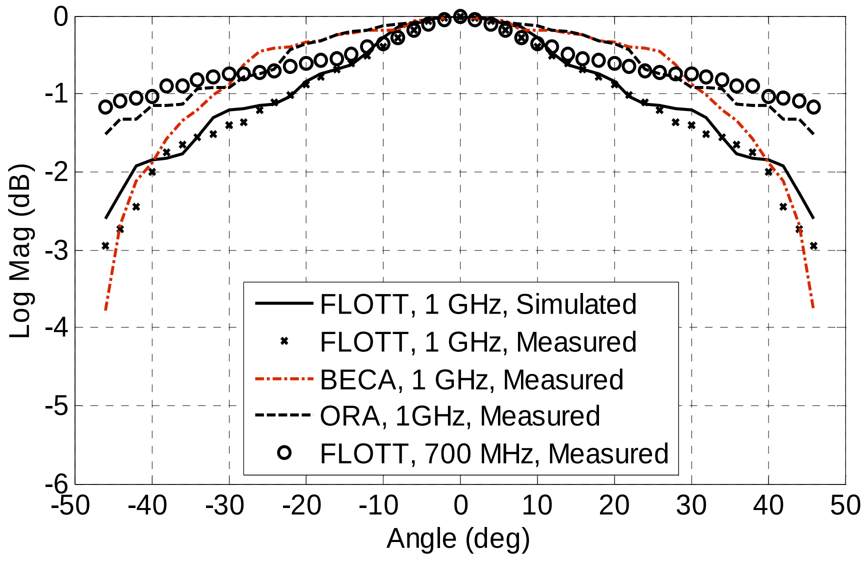


***D*-plane**
45º Cut

Scanned element pattern for the centre element of the finite array



E-plane (0º Cut)



H-plane (90º Cut)

Design Summary

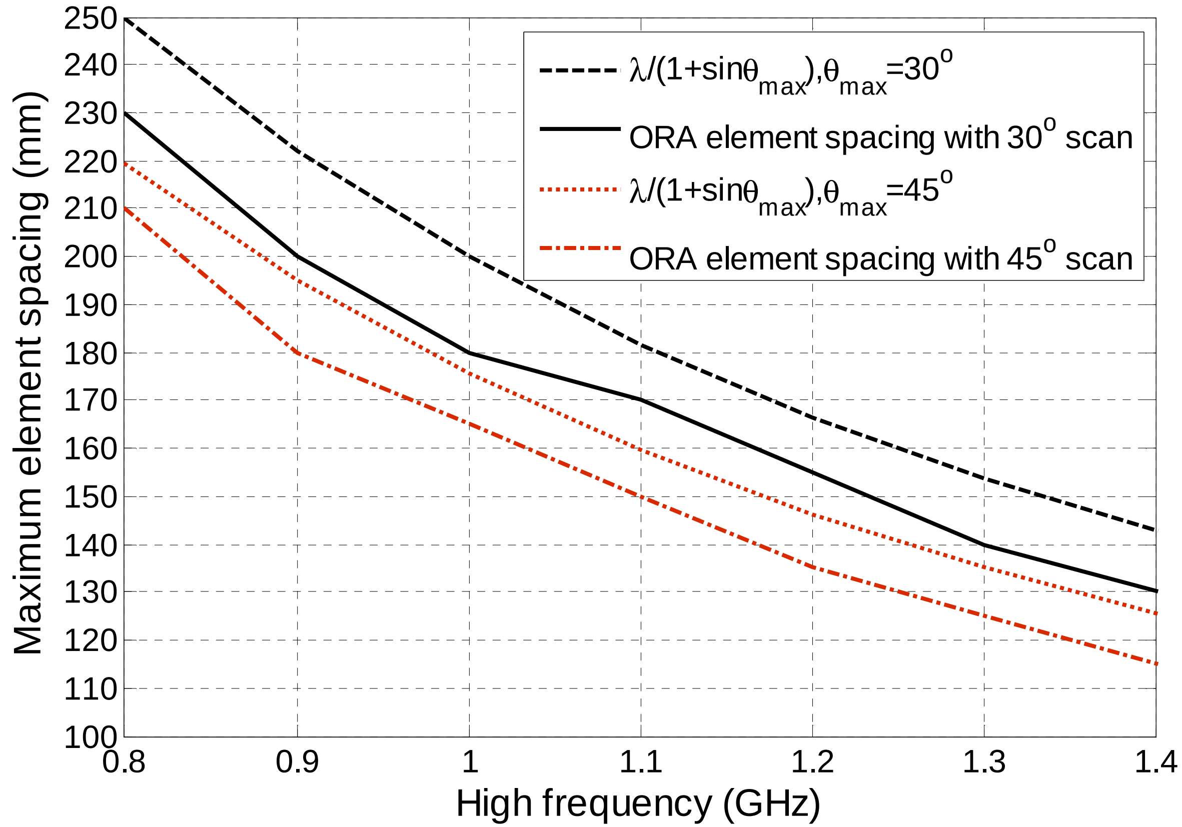
- Tapered slot antenna shows a higher cross polarization in the inter-cardinal plane (45^{o}-plane)
- A long tapered slotline is needed to produce a broad frequency bandwidth, as a result, the radiation pattern can be narrow at the high end of frequency band
- ORA exhibits a broad radiation pattern and a smooth cross polarisation performance over the entire scan range

AA-mid Antenna Design for PrepSKA

The target Operating frequency band:
400MHz-1.4GHz, ±45° scan angle

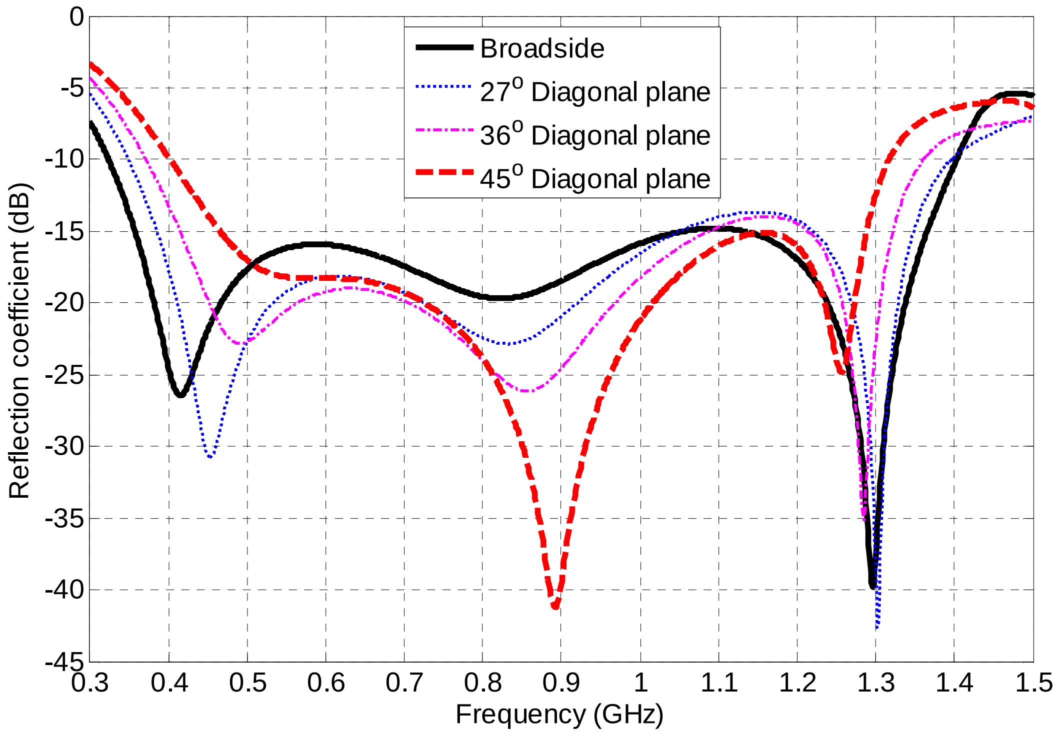
- The element separation for the AA-mid aperture array
- The feeding methods of ORA
- The ORA finite array analysis

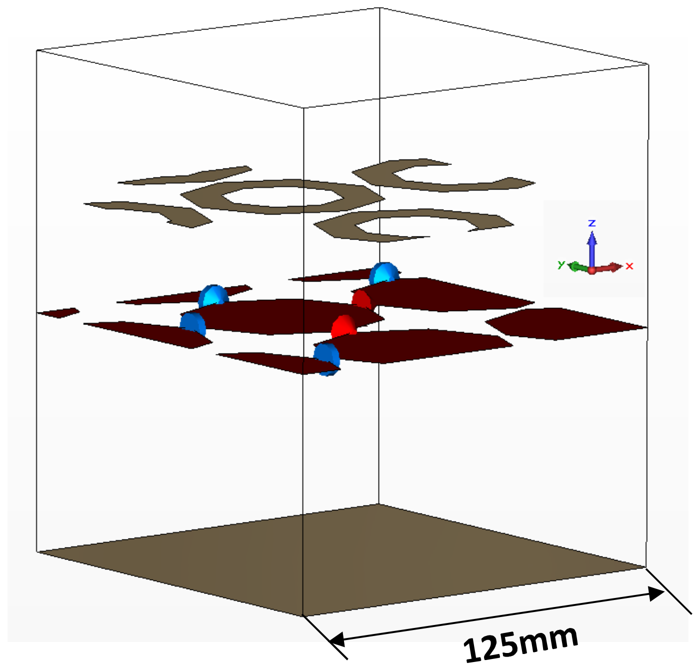
Element separation for AA-Mid



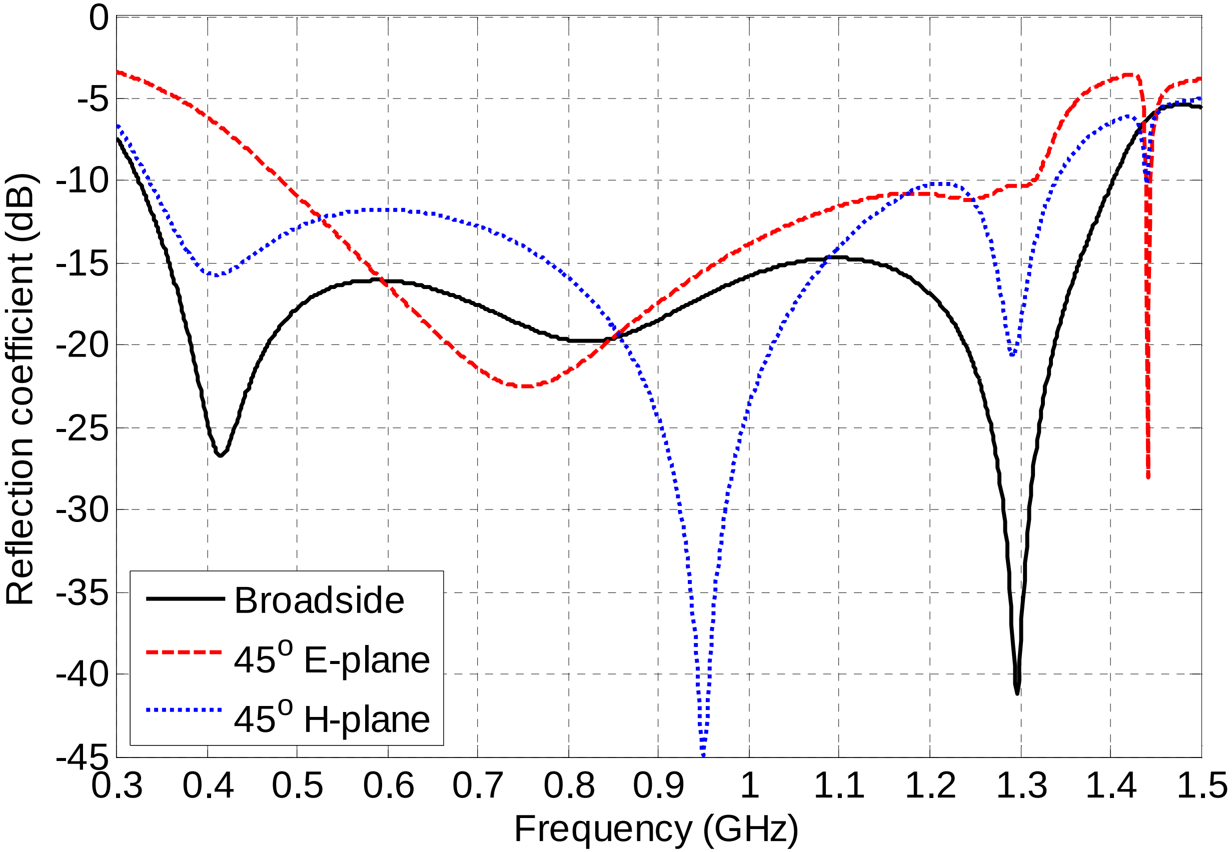
The maximum element spacing in the array is limited by the appearance of grating lobes, and the electromagnetic interactions between the elements with scan, the resulting numbers are not normally the same

The infinite ORA array with 125 mm element separation



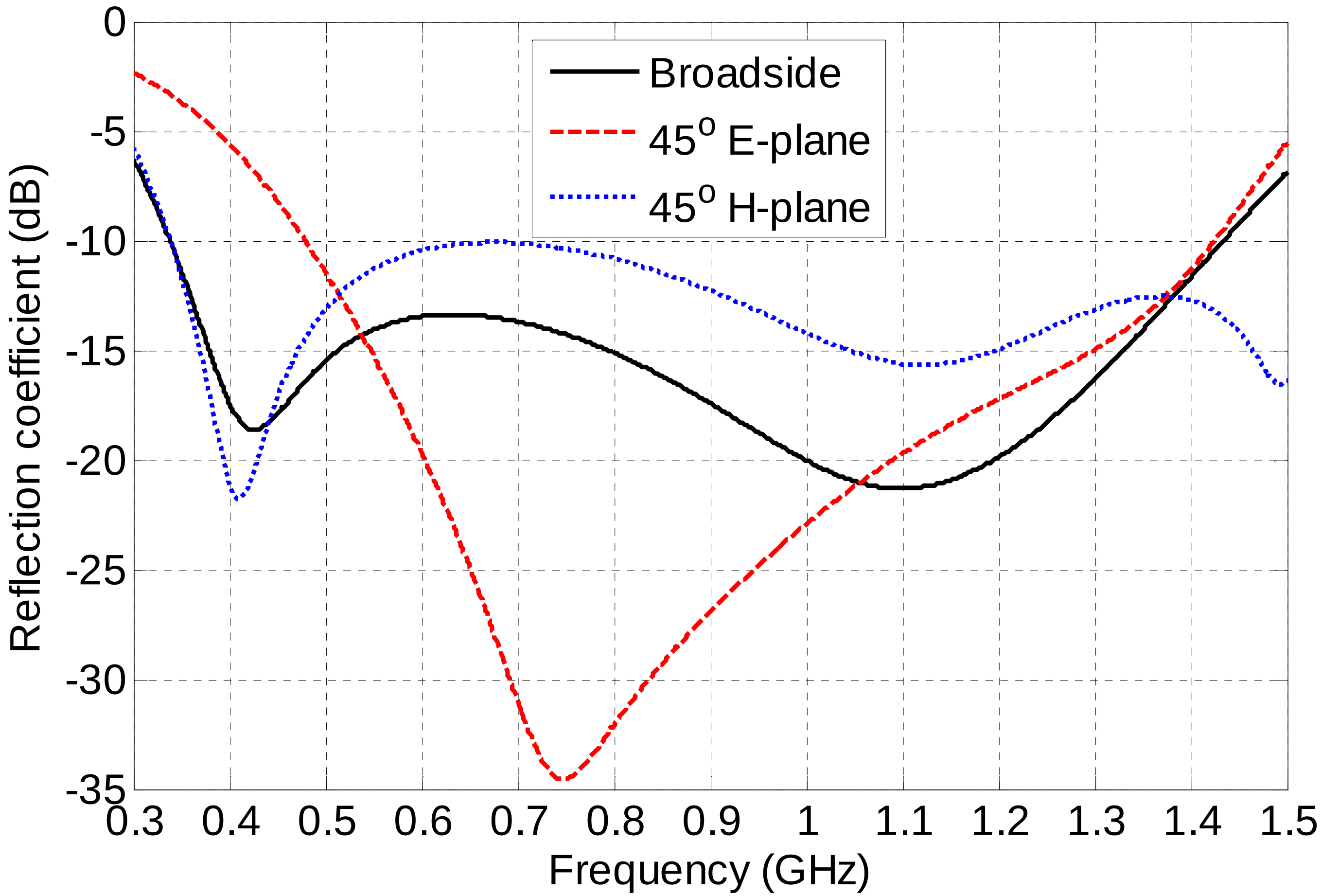


The infinite ORA array with 125mm element separation



400MHz-1350MHz, maximum 45º scan angle

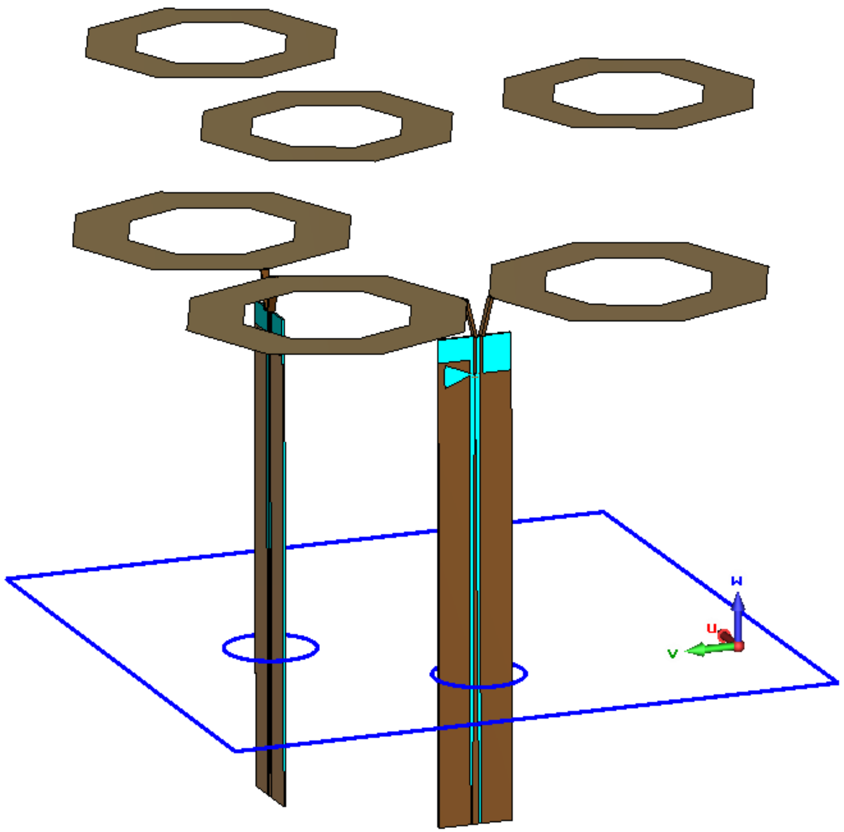
The infinite ORA array with 112 mm element separation



450MHz-1400MHz, maximum 45º scan angle

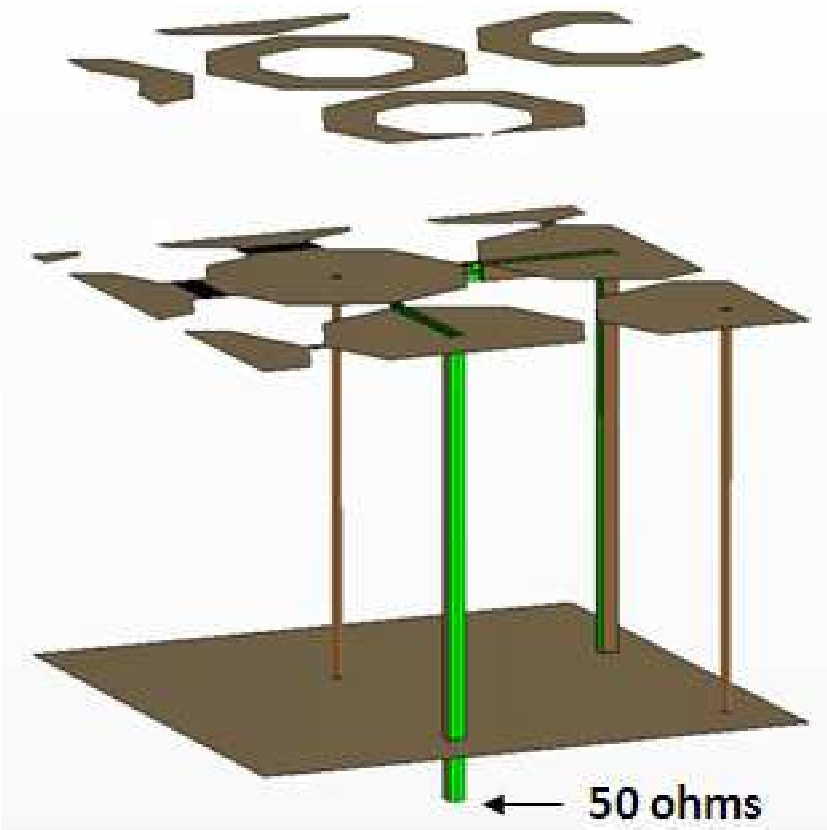
Feeding methods for ORA

Coplanar waveguide feed for EM measurements, SKADS

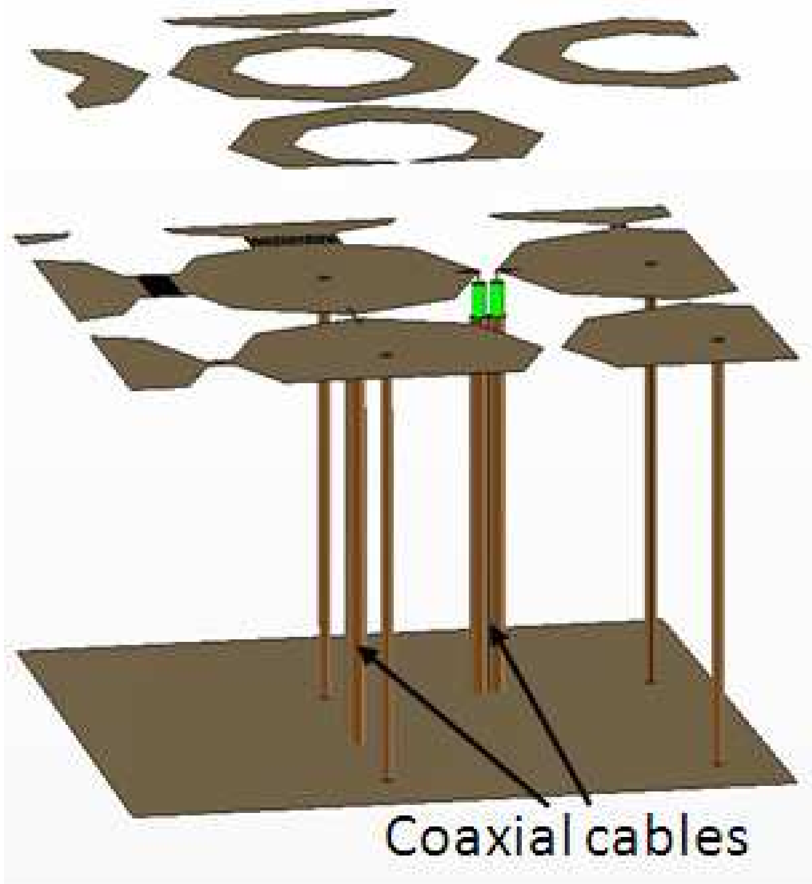


50 ohms single-ended output, feasible for radiation pattern measurement, but this balun can be lossy!

Single-ended and differential feeding methods

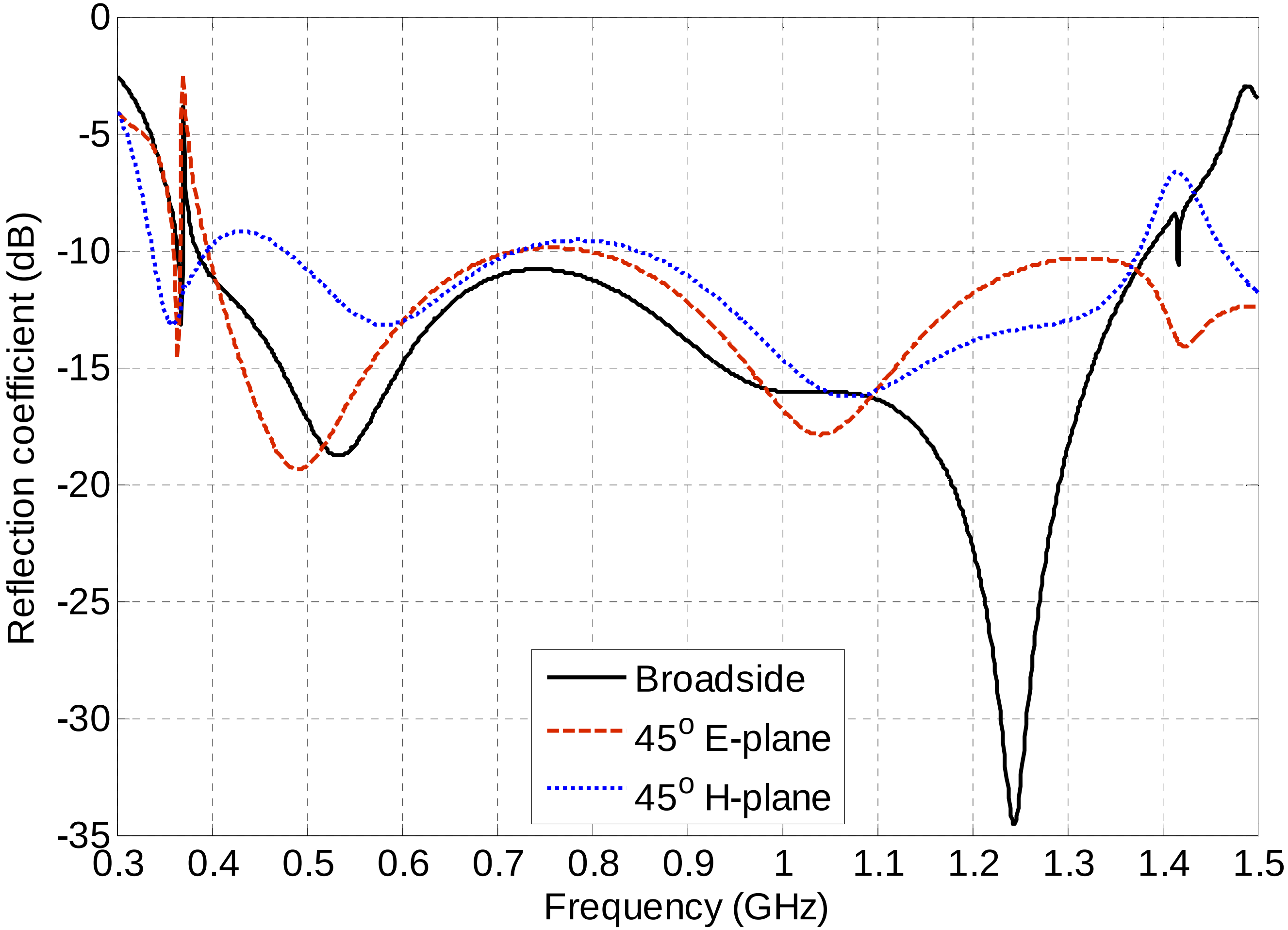


The single-ended stripline

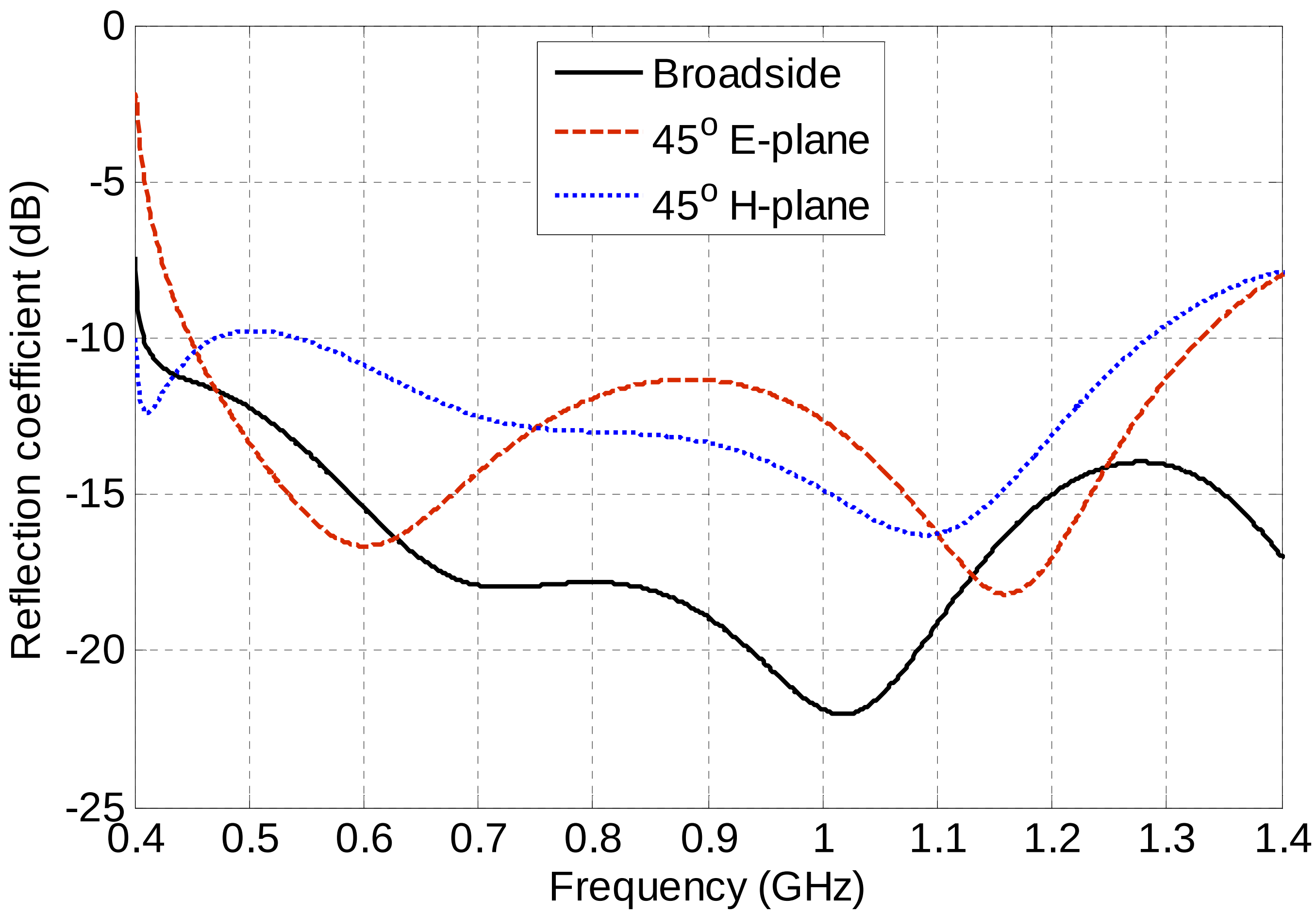


Differential coaxial cable feeding

ORA performance with 50ohms stripline feed, 112mm

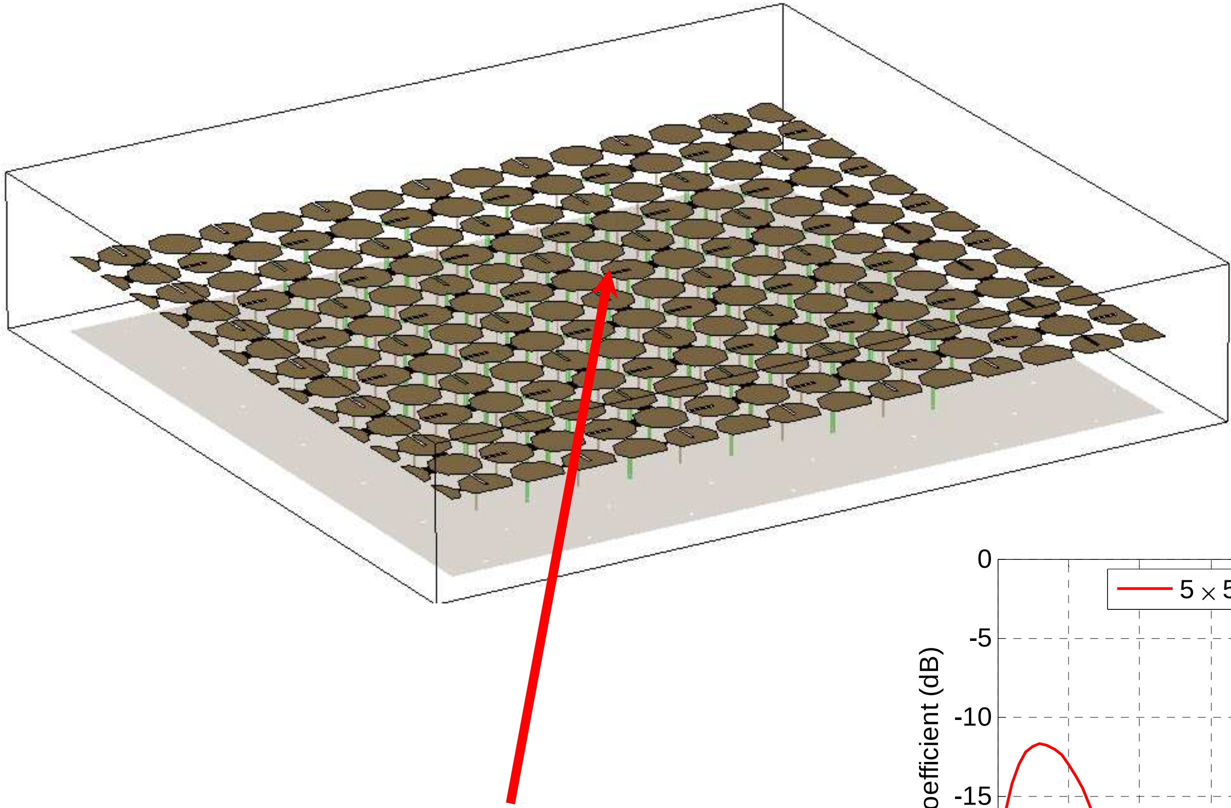


ORA performance with differential coaxial cable feeds, 112mm element spacing

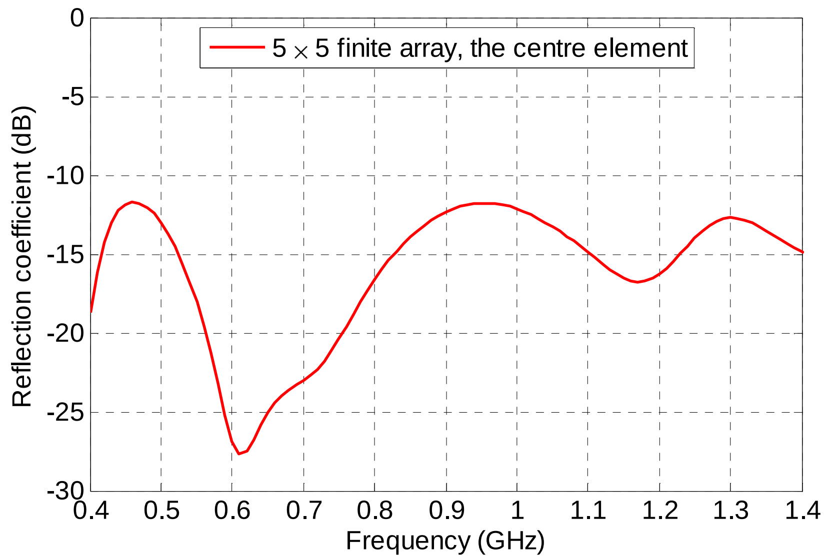


The ORA Finite Array Analysis

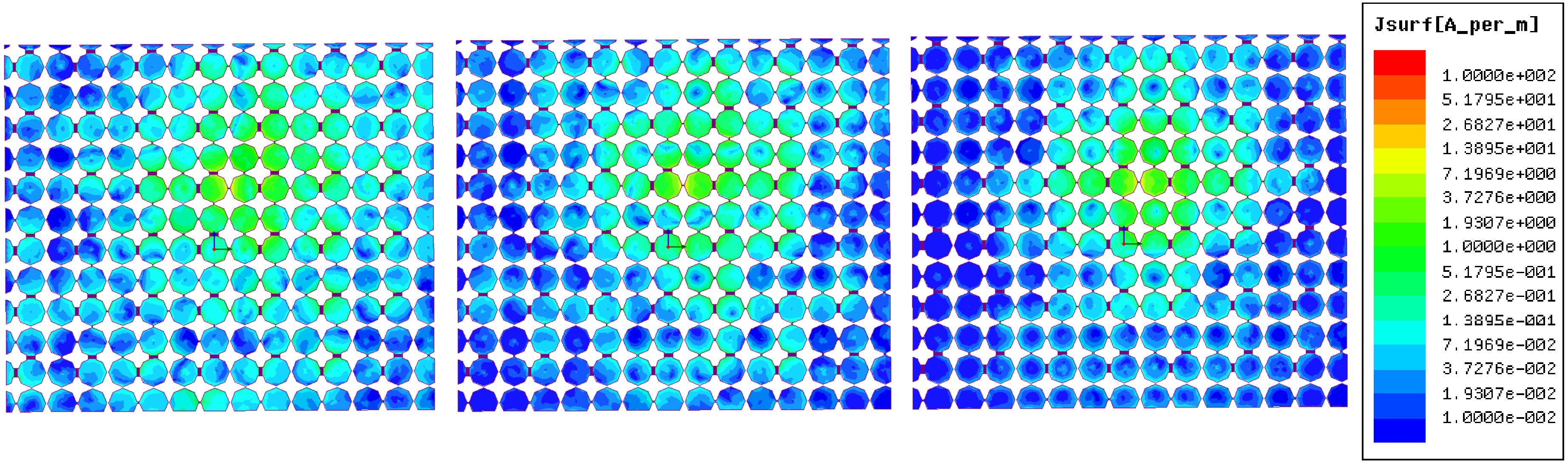
The passive reflection coefficient for ORA with the stripline feed



The centre element in a 5×5 array with all the rest elements are loaded

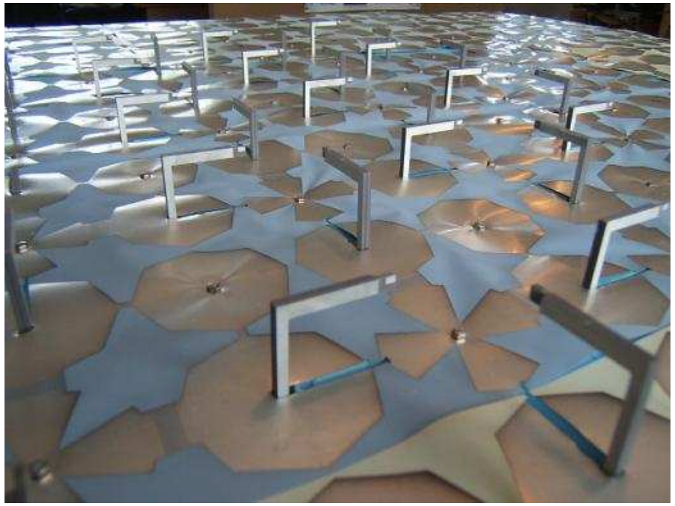


Surface current on the conducting sheets for a single element excitation

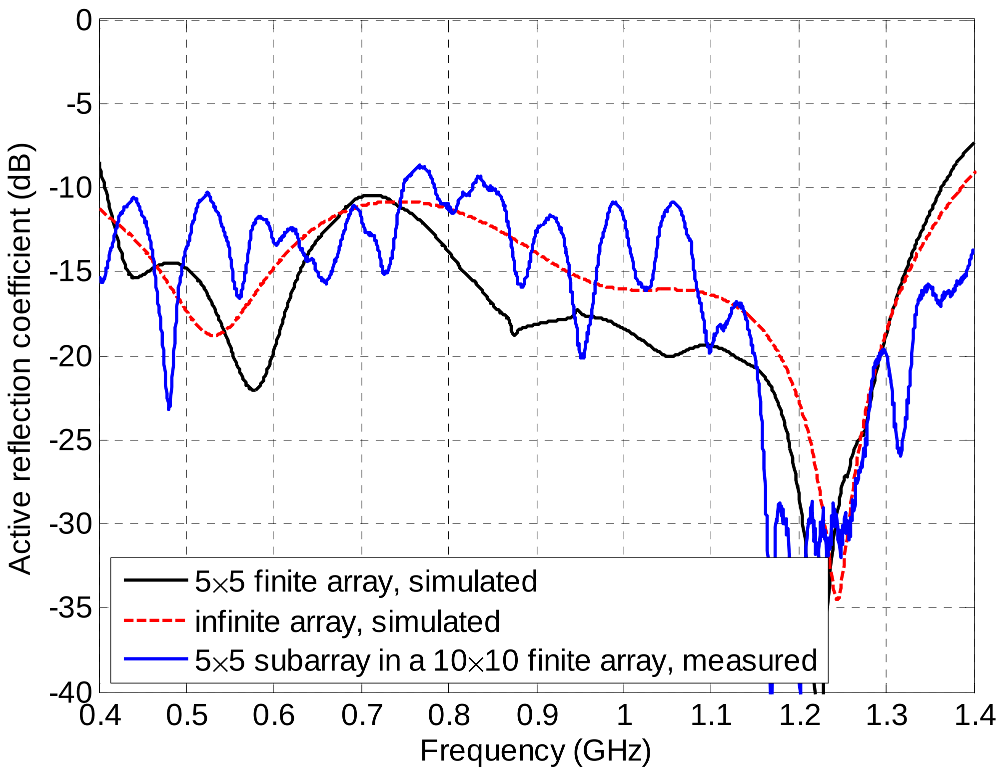


400MHz **900MHz** **1400MHz**

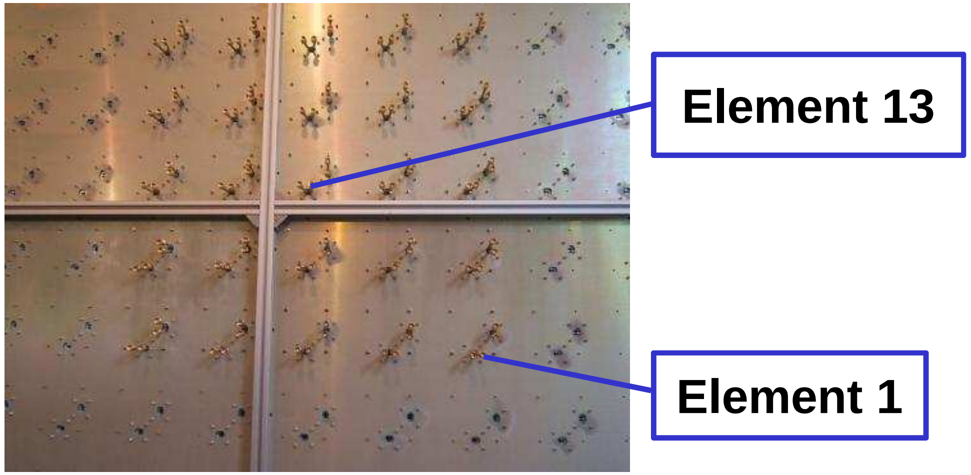
Single-ended Stripline feed for the 5×5 subarray of the 10×10 finite array tile

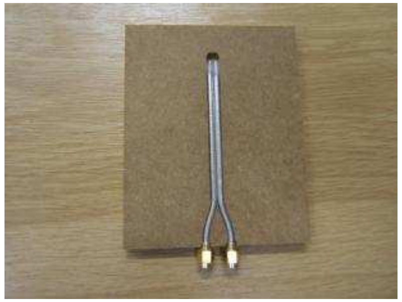


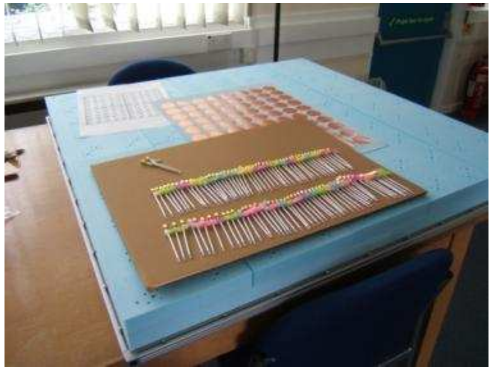
The active reflection coefficient

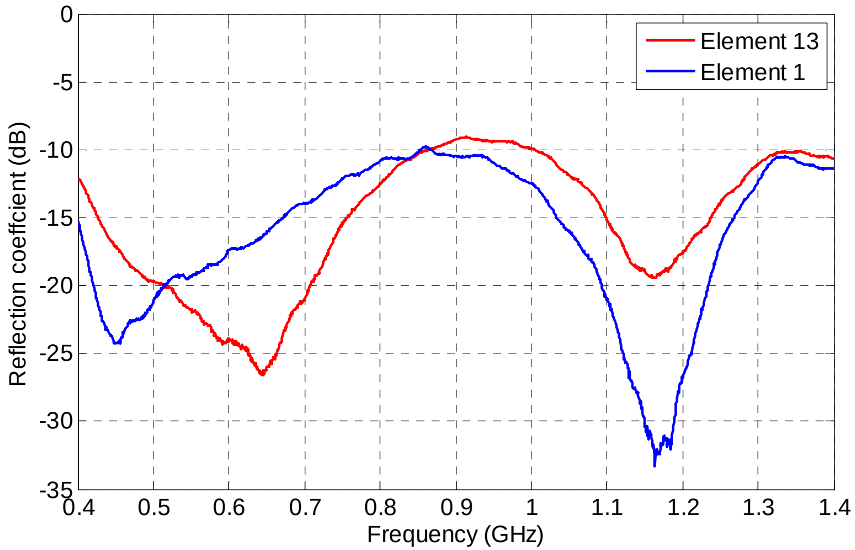


Differential feeding method, passive reflection coefficient measured









Conclusions

- Three different structures have been designed and performance compared
  - The Vivaldi is well known and provides broadband performance
    - It suffers from potentially high cross-polarisation in the inter-cardinal planes
    - Care must be taken to avoid narrow frequency resonances in the input impedence
  - BECA offers slightly improved cross polarisation and less susceptibility to input resonances but is potentially more complex
  - ORA provides a planar array alternative which is promising, has low scan loss and lower cross-polarisation with potentially simpler construction but requires further investigation for large scale manufacture

Thank you very much!