The development of a CSIRO MKIII wideband phased array feed

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Introduction

The motivation for this design was to develop a 40 element array as a technology demonstrator for SKA survey

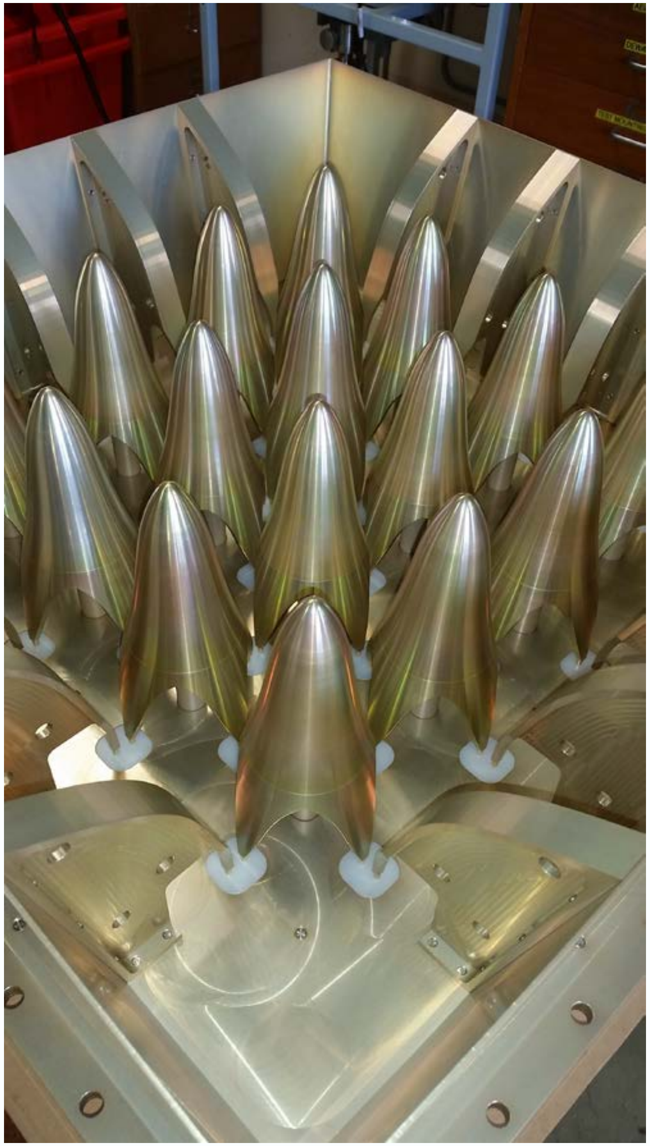
It has also become a demonstrator for a possible future upgrade of ASKAP and a potential cryogenic PAF for the Parkes Radio Telescope

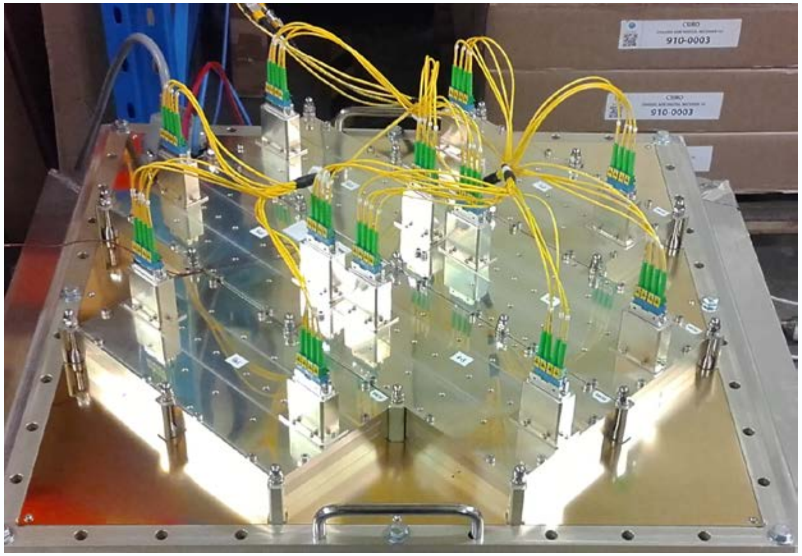
Frequency range optimized for 0.65-1.65GHz

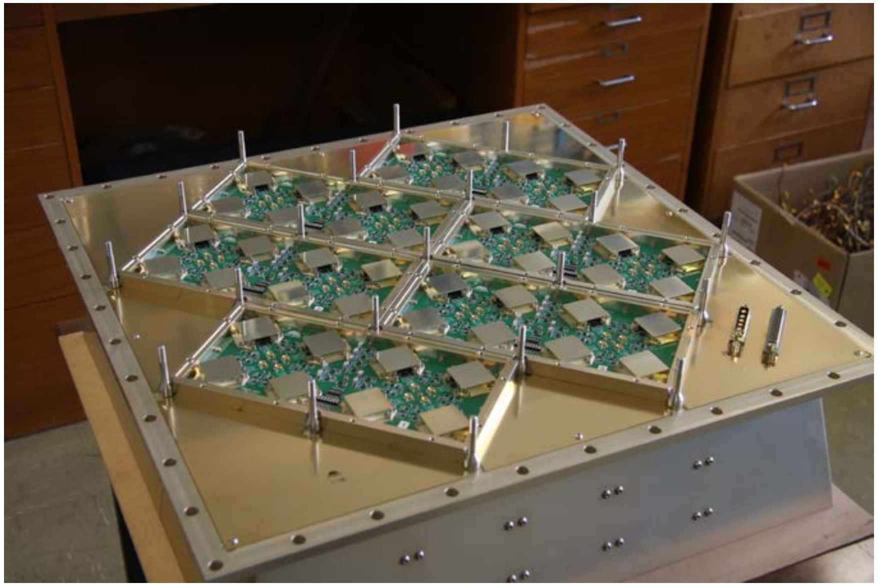
We have not considered cooling

This design was intended for a low RFI environment

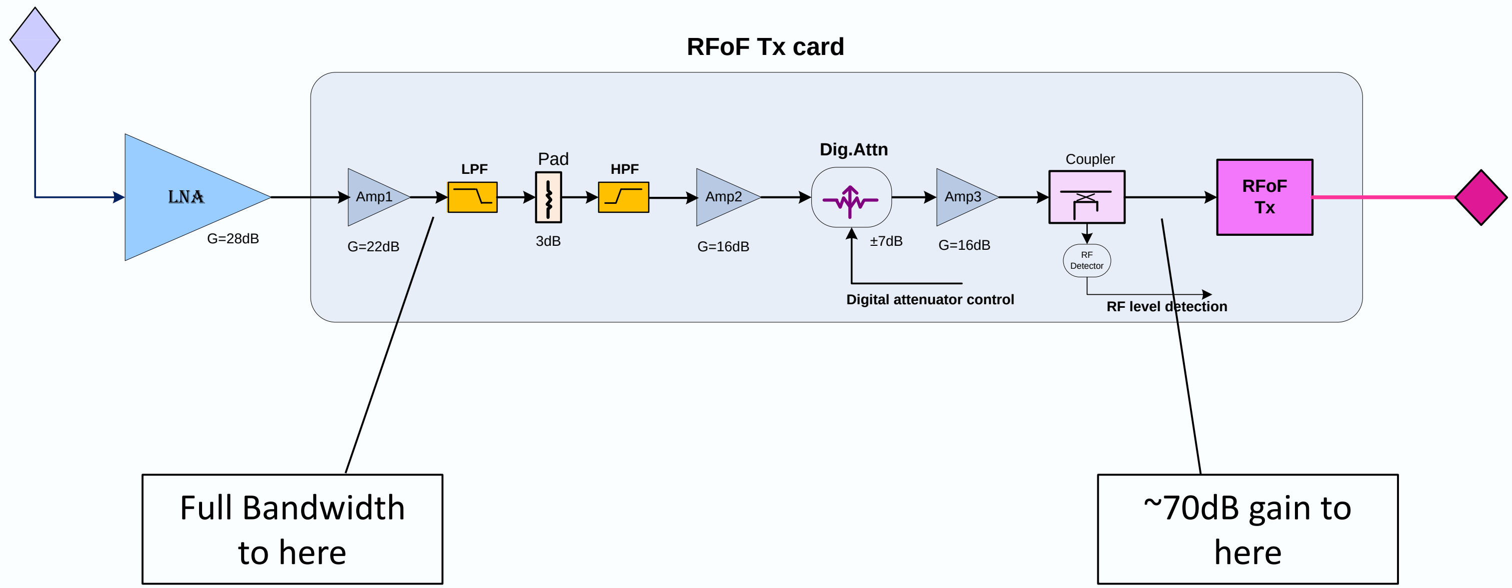
The LNAs use commercial HEMT transistors

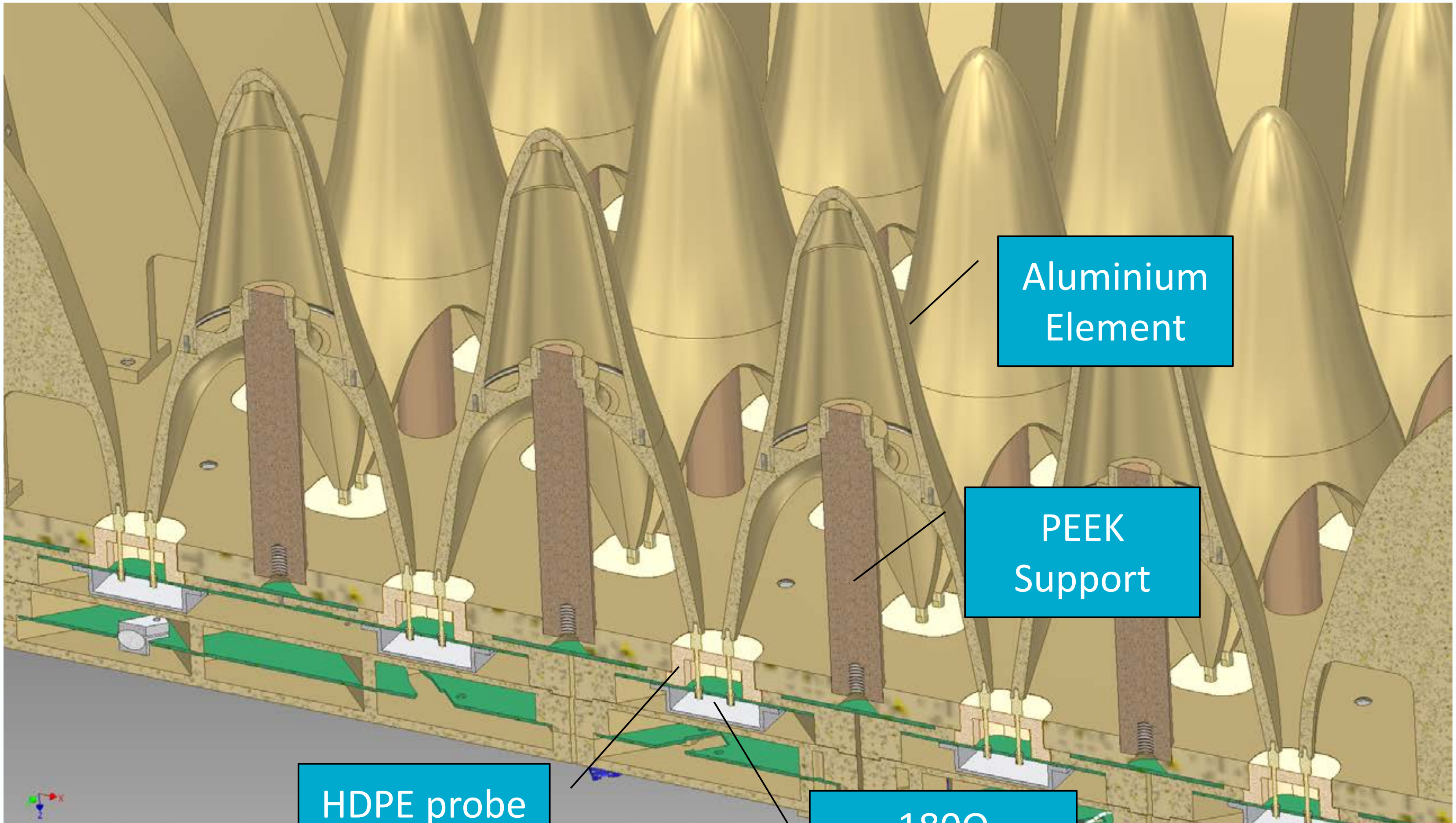






The RF signal path

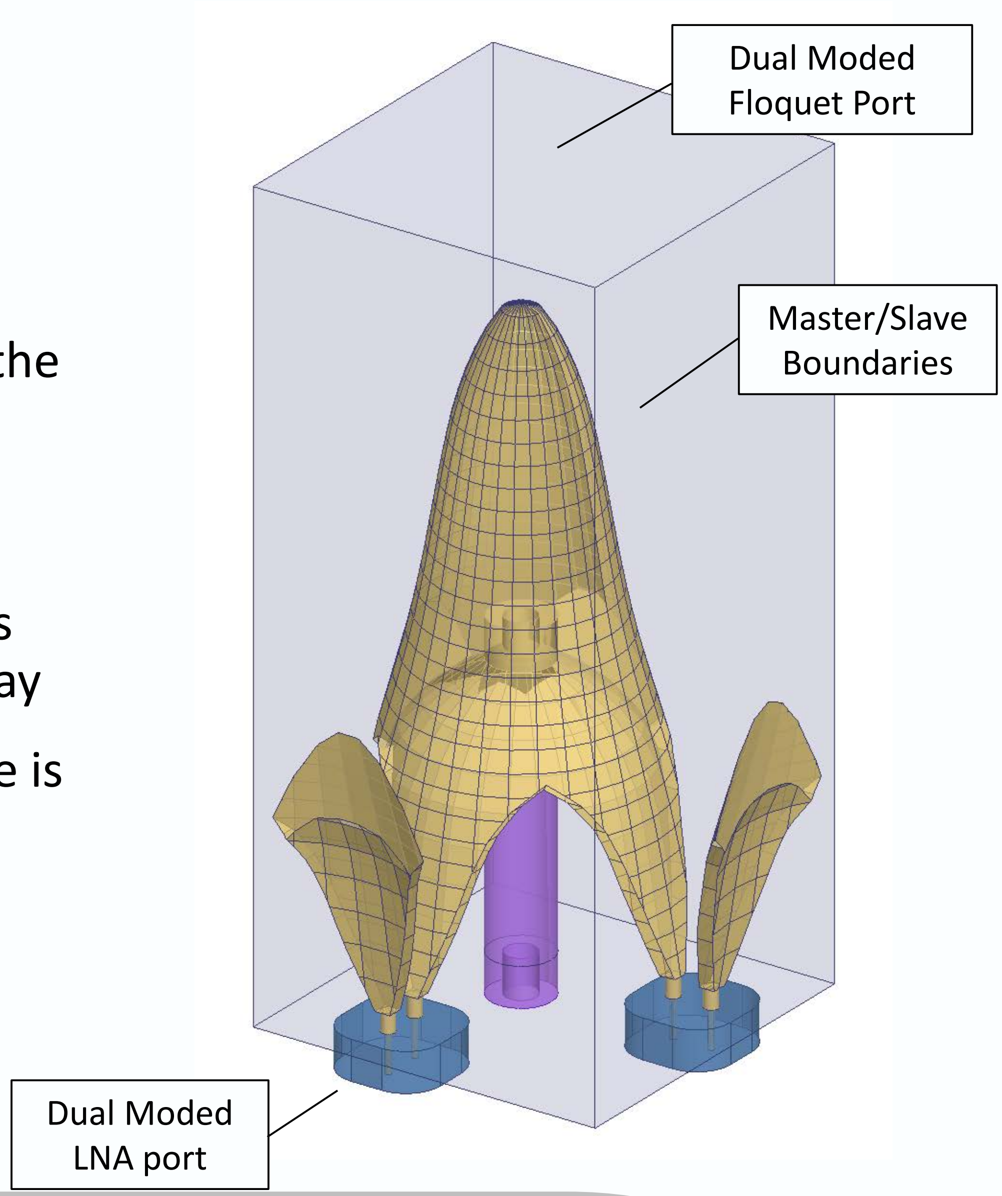


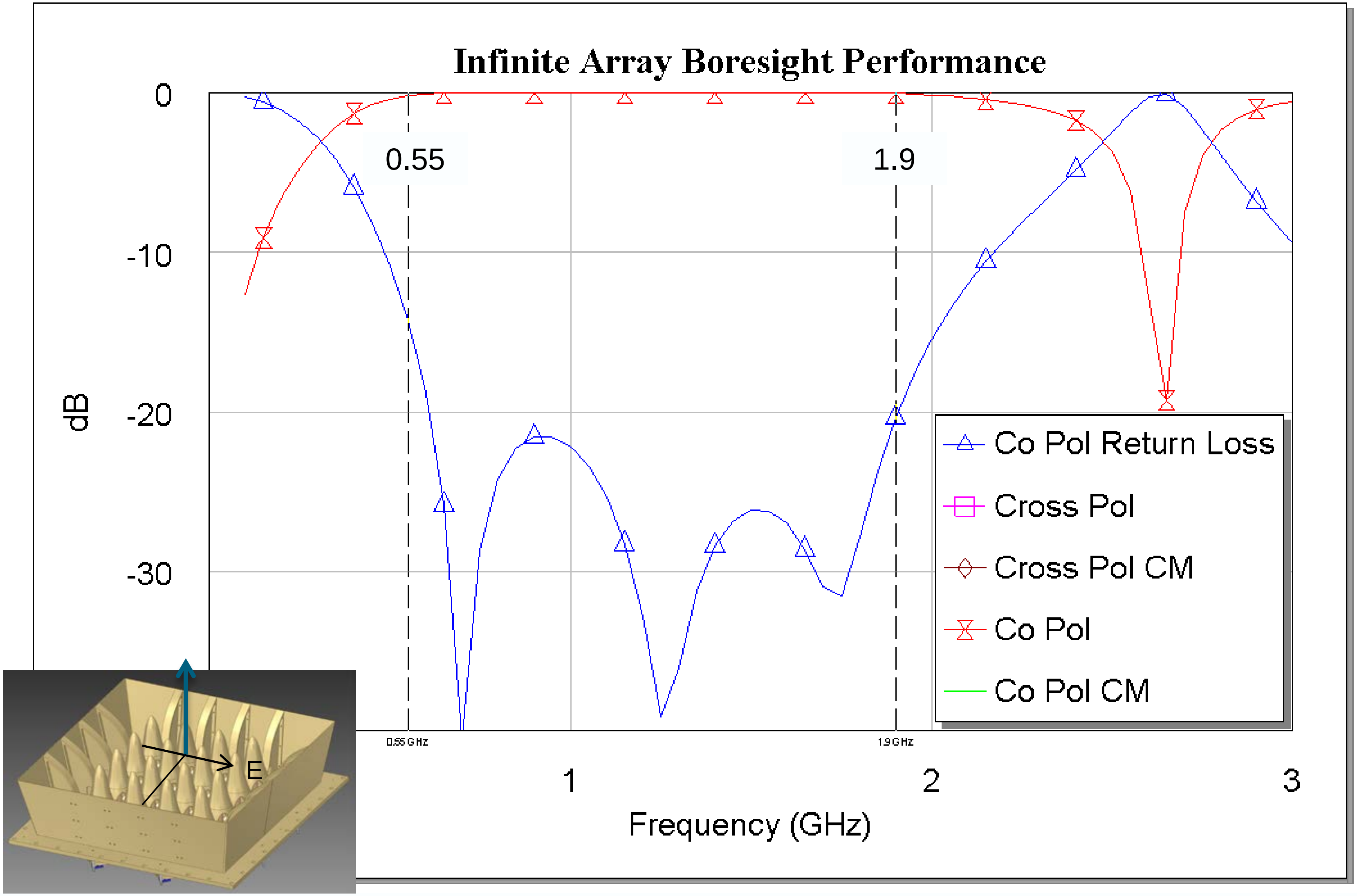

Aluminium Element
PEEK Support
HDPE probe support
180Ω Differential LNA inputs

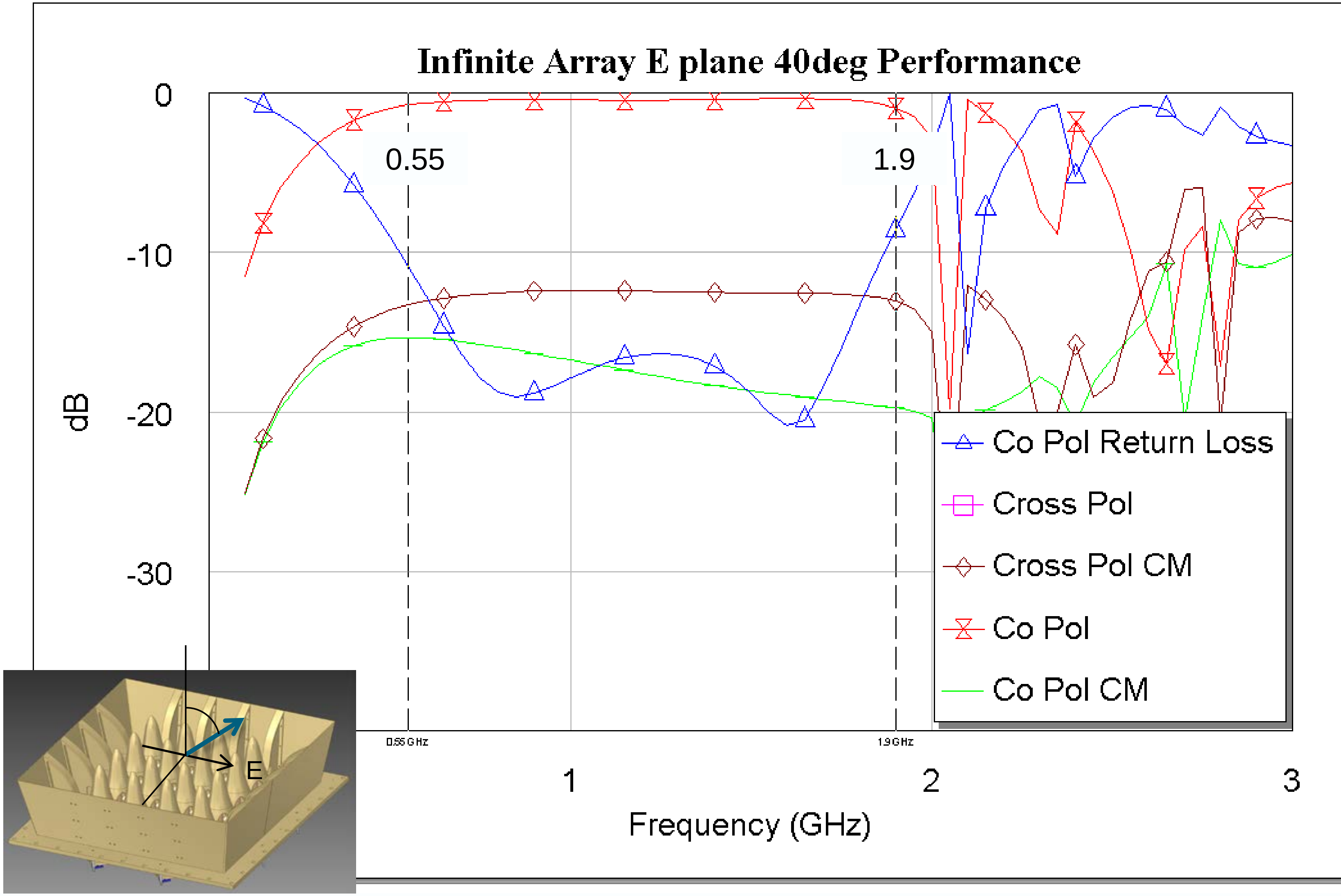
CSIRO

The design process

- Constrain the length of the elements to ensure low loss
- With an infinite array, optimize the element geometry to achieve maximum boresight return loss
- Design the edge elements such that the impedance at the edges resembles that of an infinite array
- Check infinite array performance is acceptable over angles required for good dish illumination
- Check array/LNA noise match

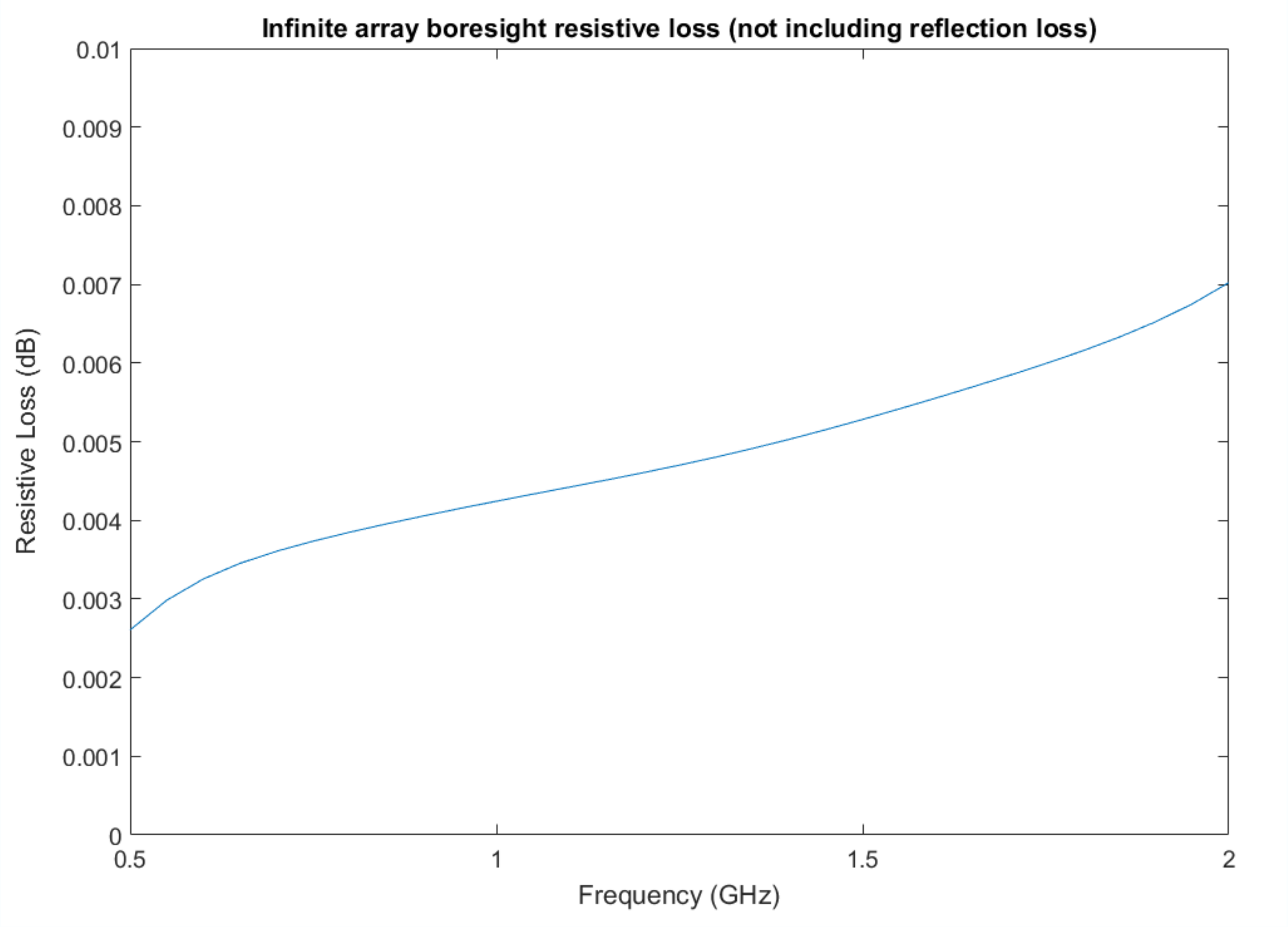



Infinite Array Boresight Performance
0
-10
-20
-30
dB
0.55
1.9
0.55 GHz
1.9 GHz
1
2
3
Frequency (GHz)
Co Pol Return Loss
Cross Pol
Cross Pol CM
Co Pol
Co Pol CM
E


Infinite Array E plane 40deg Performance
0
-10
-20
-30
dB
0.55
1.9
0.55 GHz
1.9 GHz
1
2
3
Frequency (GHz)
Co Pol Return Loss
Cross Pol
Cross Pol CM
Co Pol
Co Pol CM
E

Simulated Element Loss (HFSS)

I'm not convinced this is realistic!

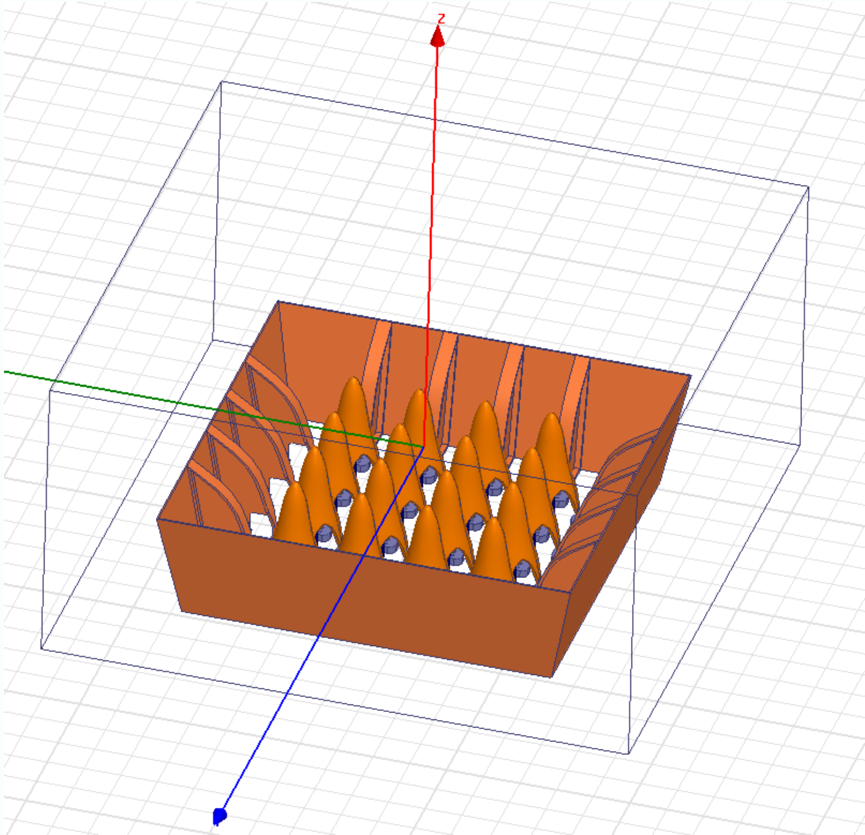


Full 5x4 PAF simulation

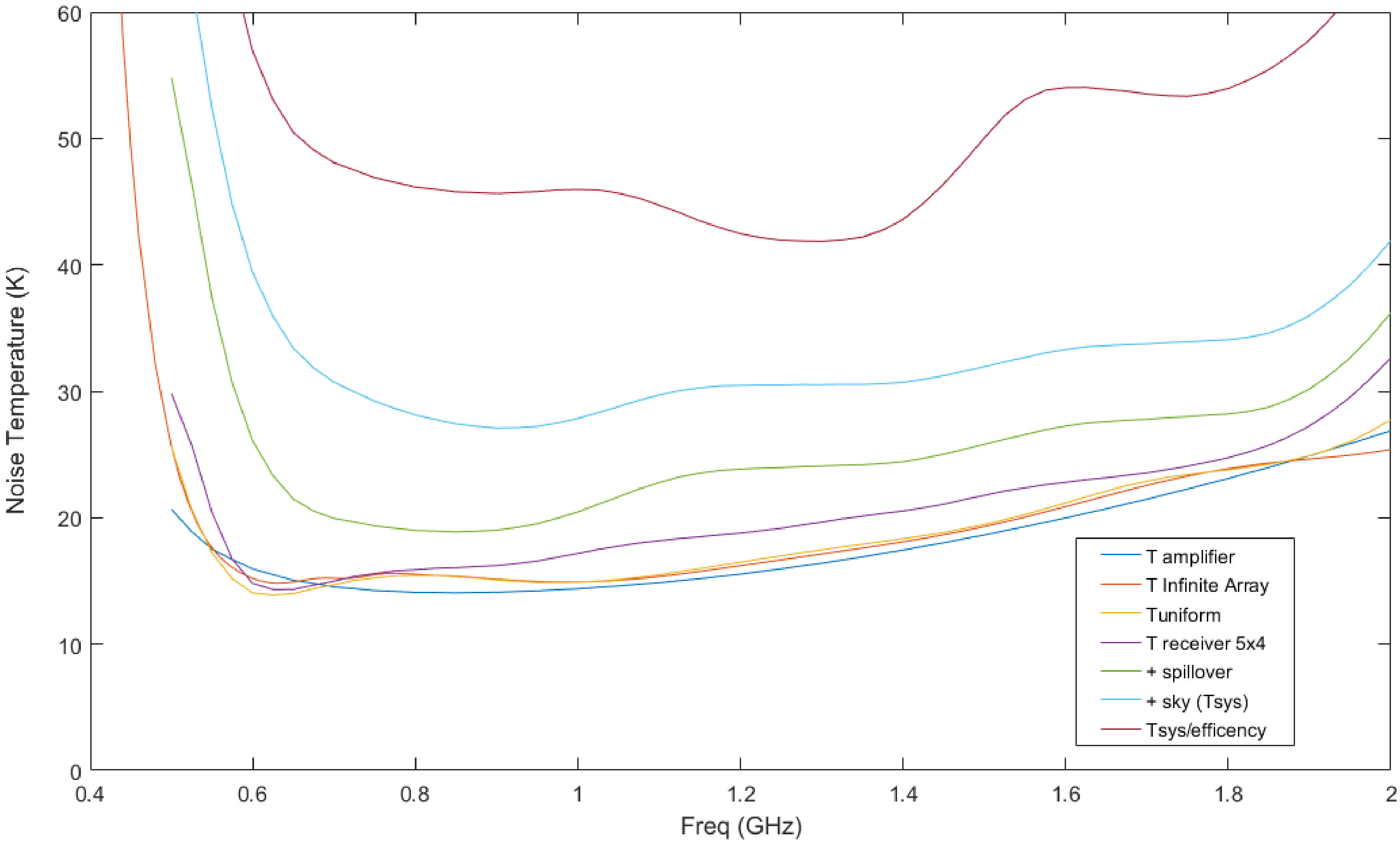
A full 80 port EM simulation of the 5x4 PAF was performed in order to accurately model finite size effects.

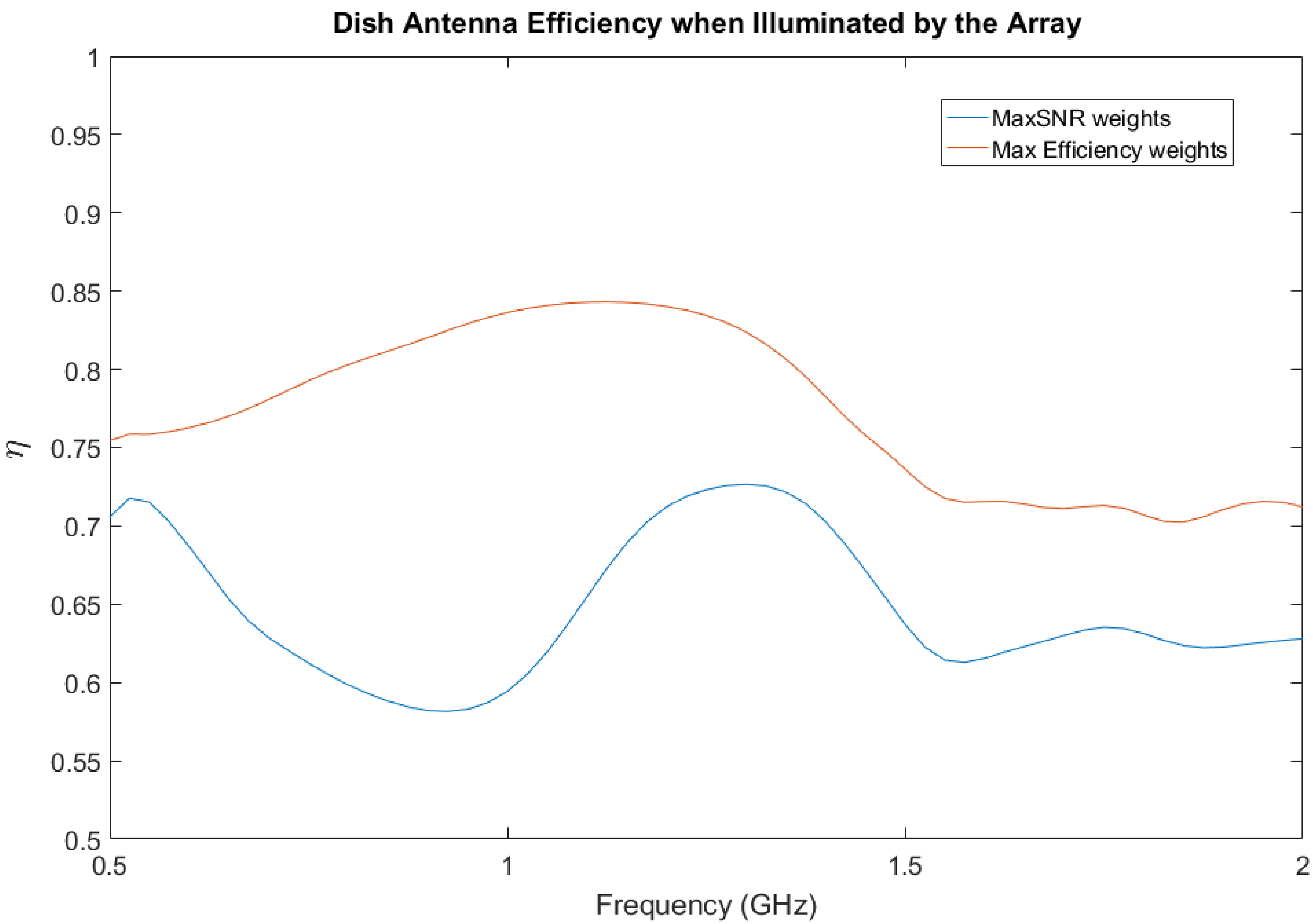
This simulation was combined with a Microwave Office simulation of the LNA to model noise covariance matrices and embedded element patterns

The noise simulation exhibits very close agreement with the infinite array simulation for most of the band.

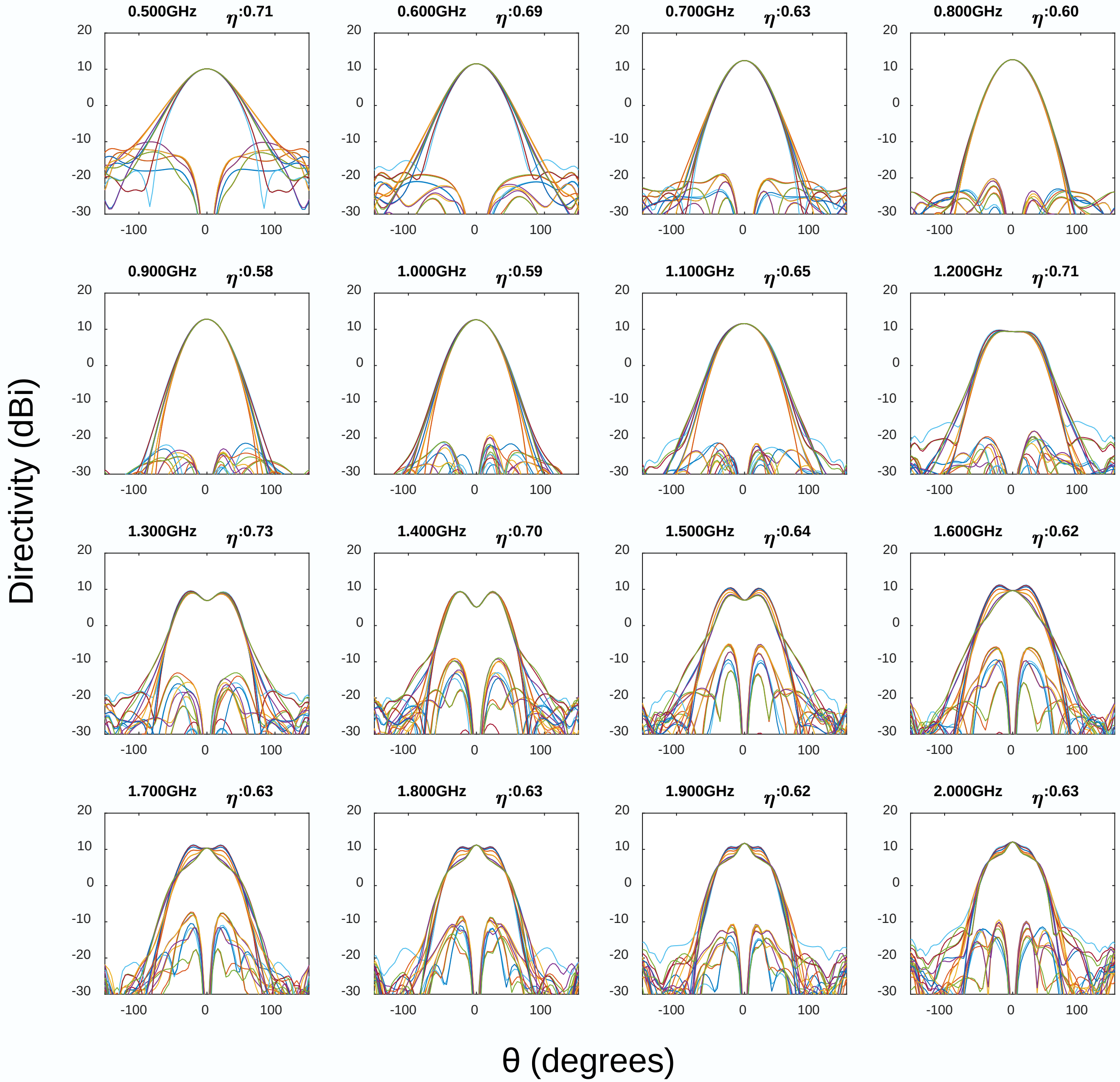


Simulated Array Performance on a Parkes Like Dish



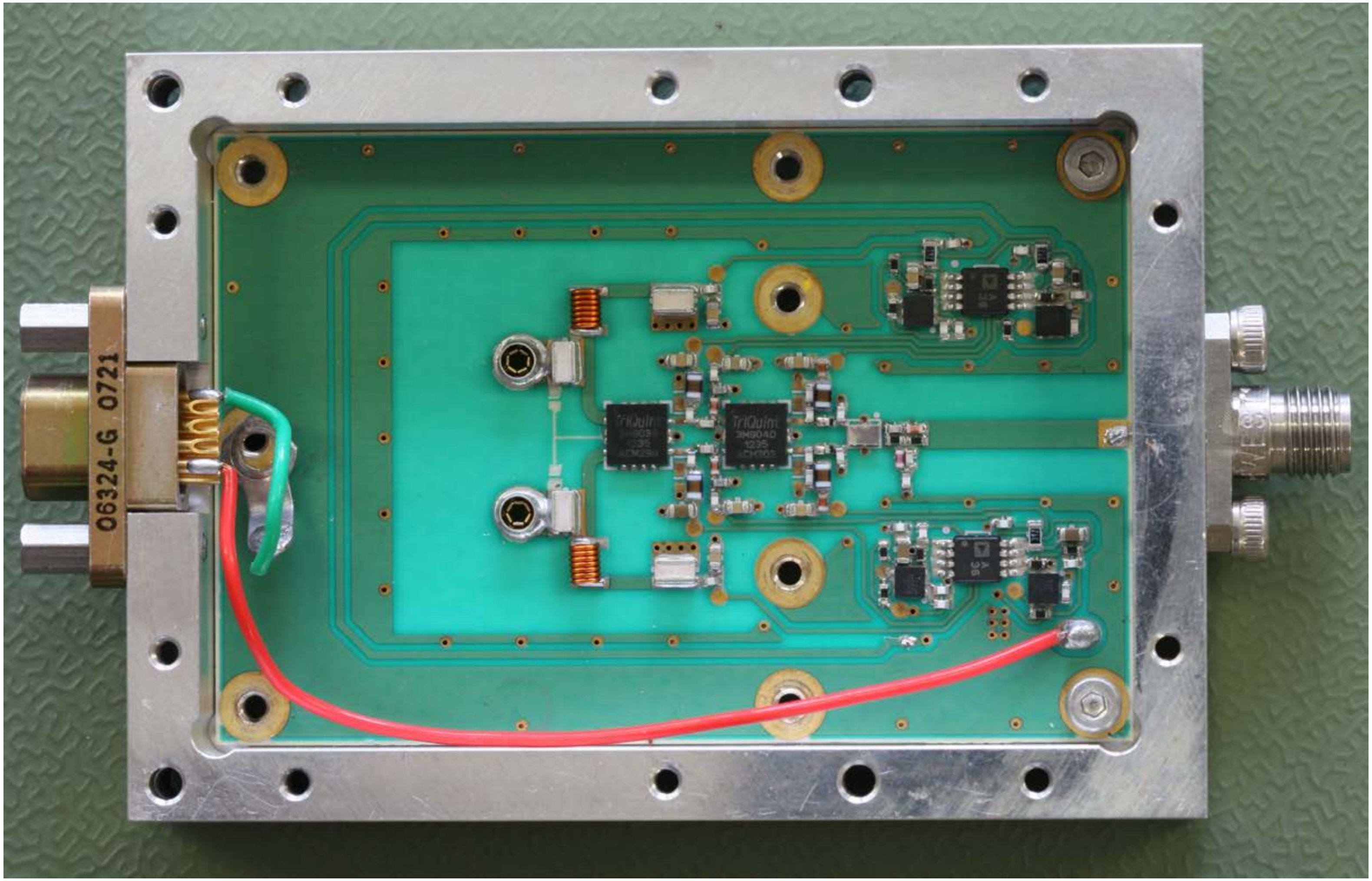


Dish Antenna Efficiency when Illuminated by the Array
MaxSNR weights
Max Efficiency weights
η
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.5
1
1.5
2
Frequency (GHz)

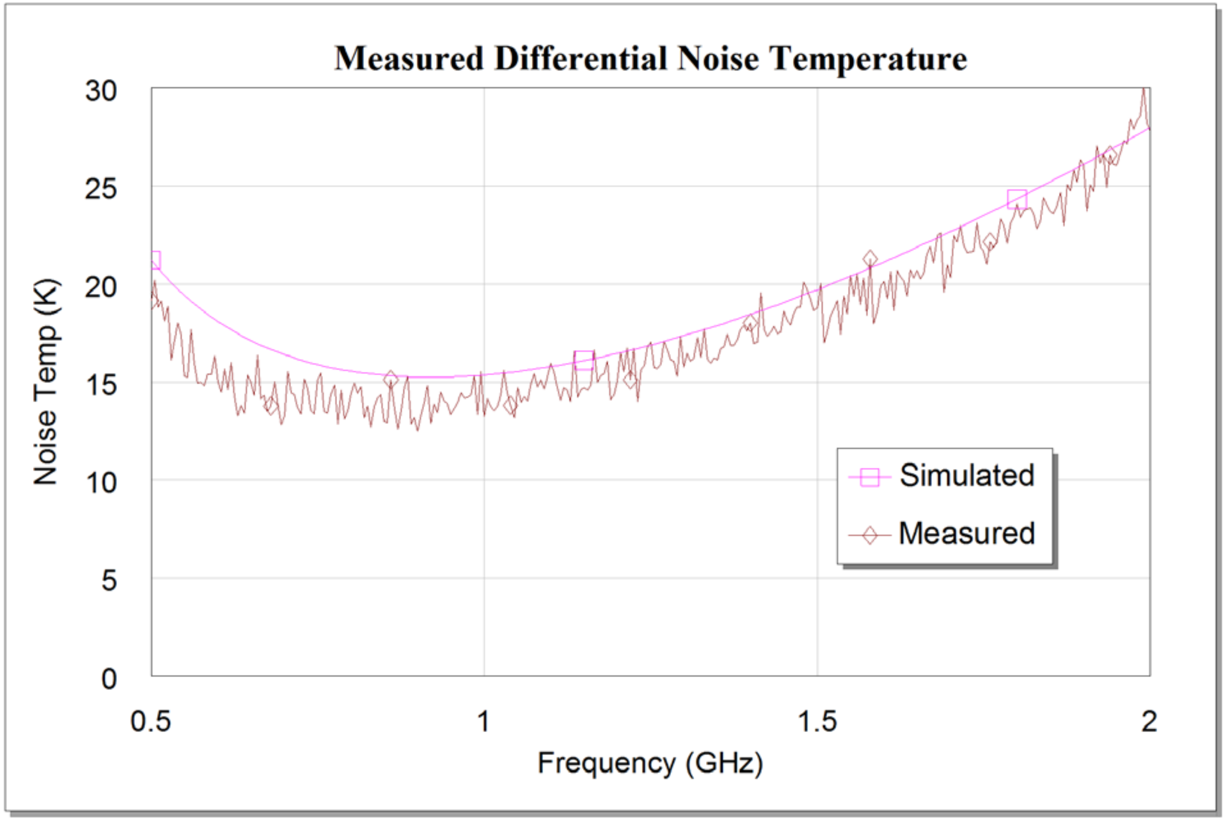


PAF modelled beam patterns using on dish Max SNR weights

The LNA design



LNA noise temperature measurements

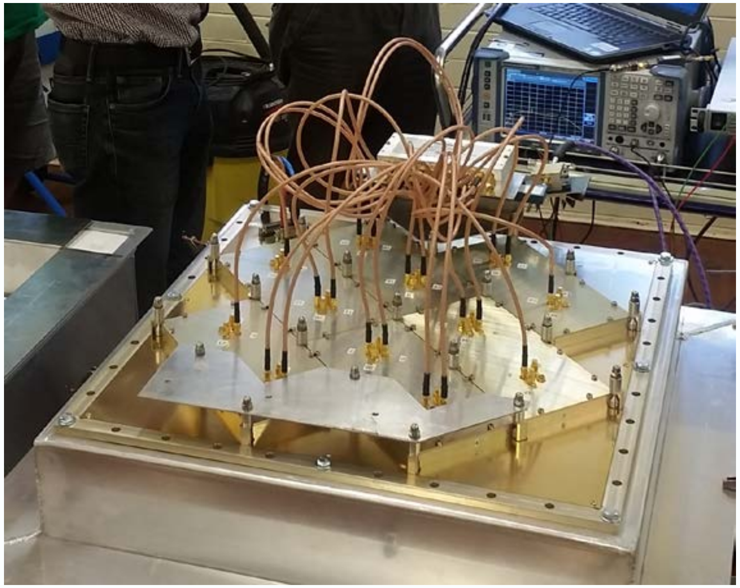


The Analogue Beamformer

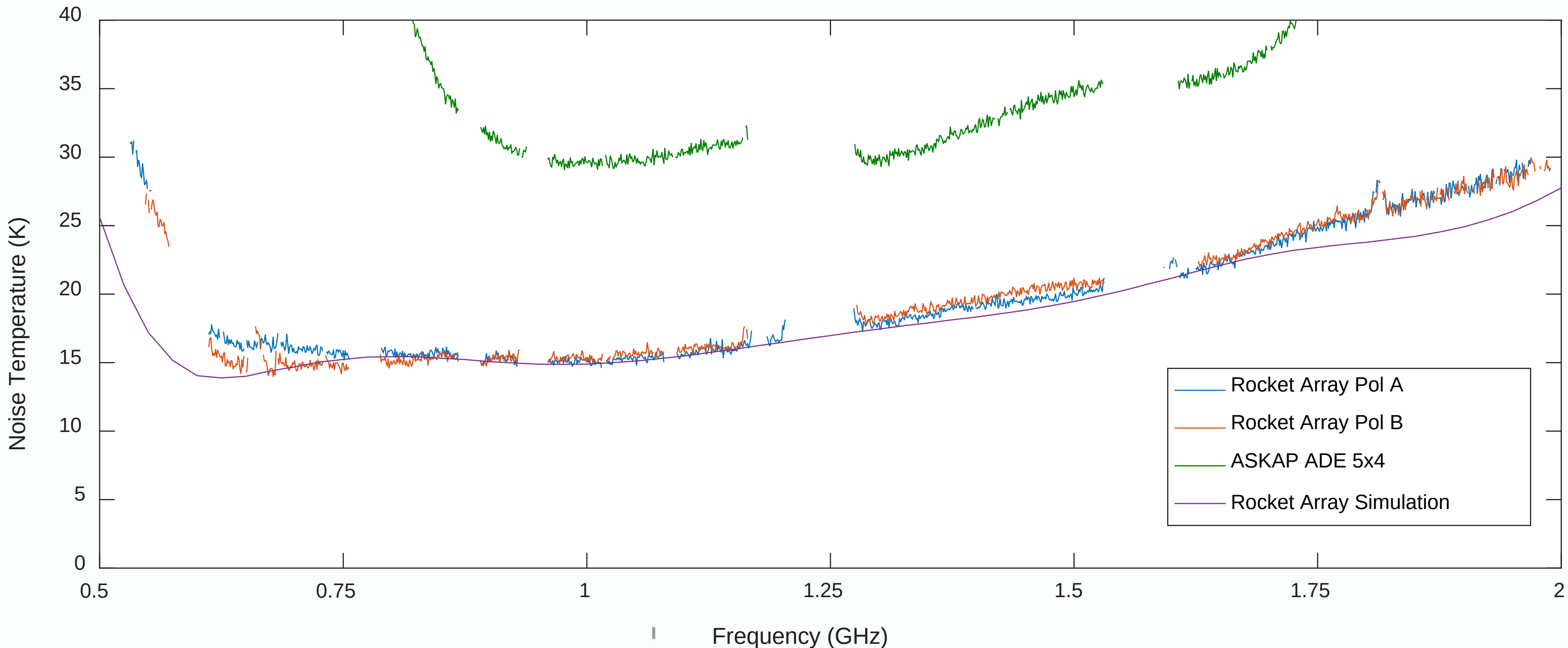
The analogue beamformer consists of a simple summing network to simulate an equal weights beamformer

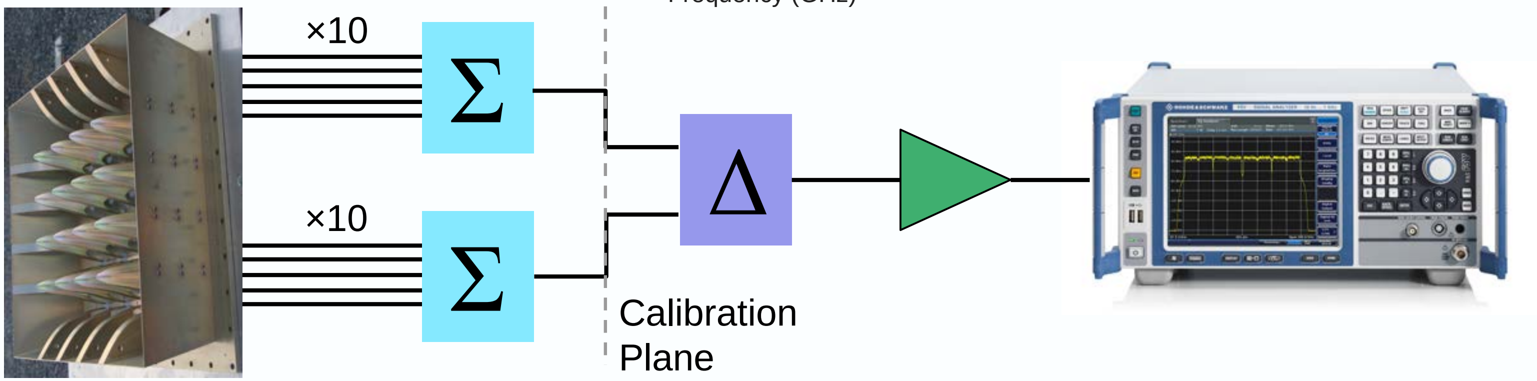
Analogue beamformer measurements with the liquid Nitrogen load did not prove very successful

To determine whether the load or the beamformer was to blame we decided to try the analoge beamformer in the Parkes aperture array setup



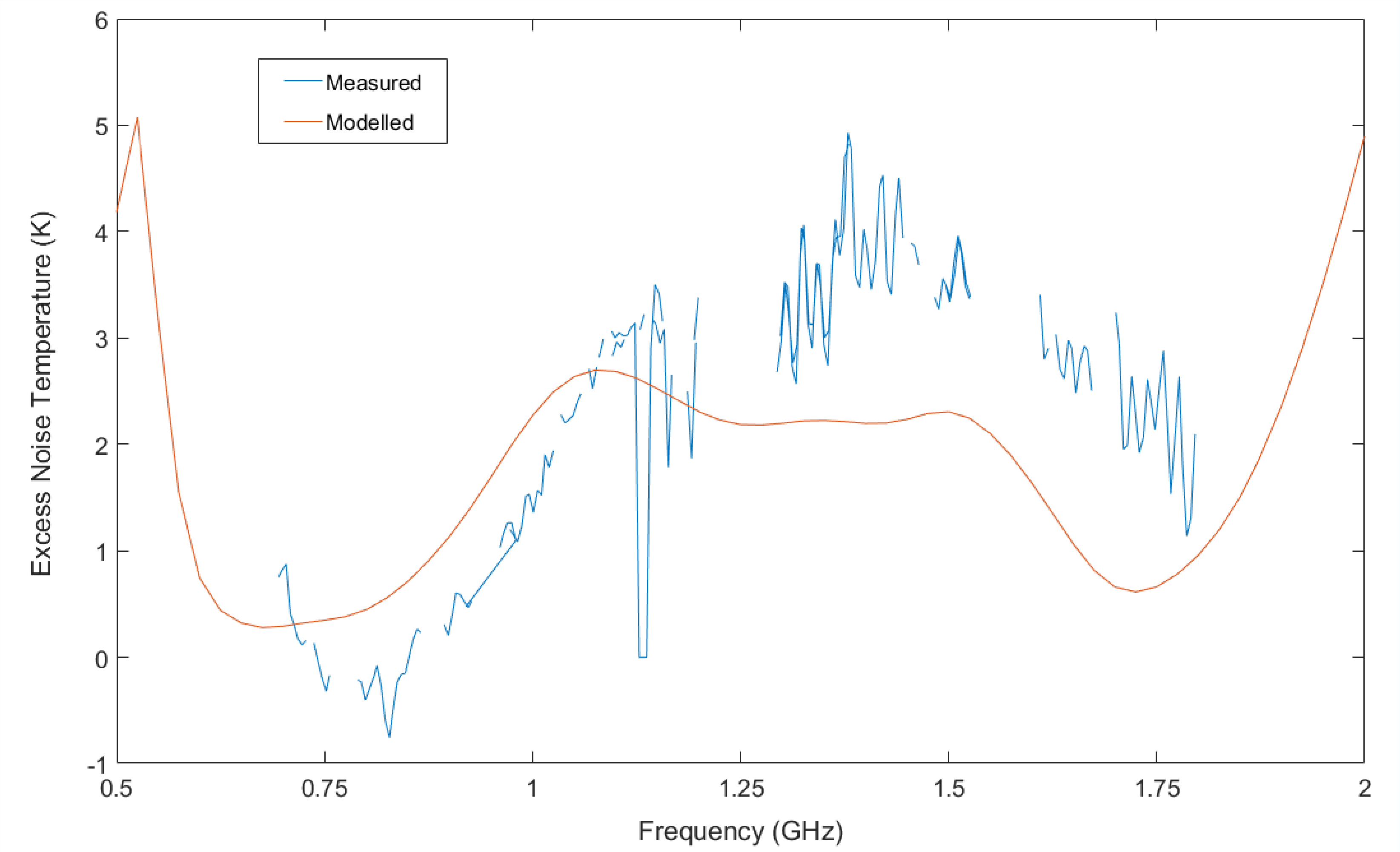
Analogue Beamformer Noise Temperature





Change in noise from uniform to dish weights

Results using the Parkes aperture array digital backend



Installing the PAF on the Parkes 64m

The array was installed on the Parkes 64m antenna in May for a three day measurement campaign

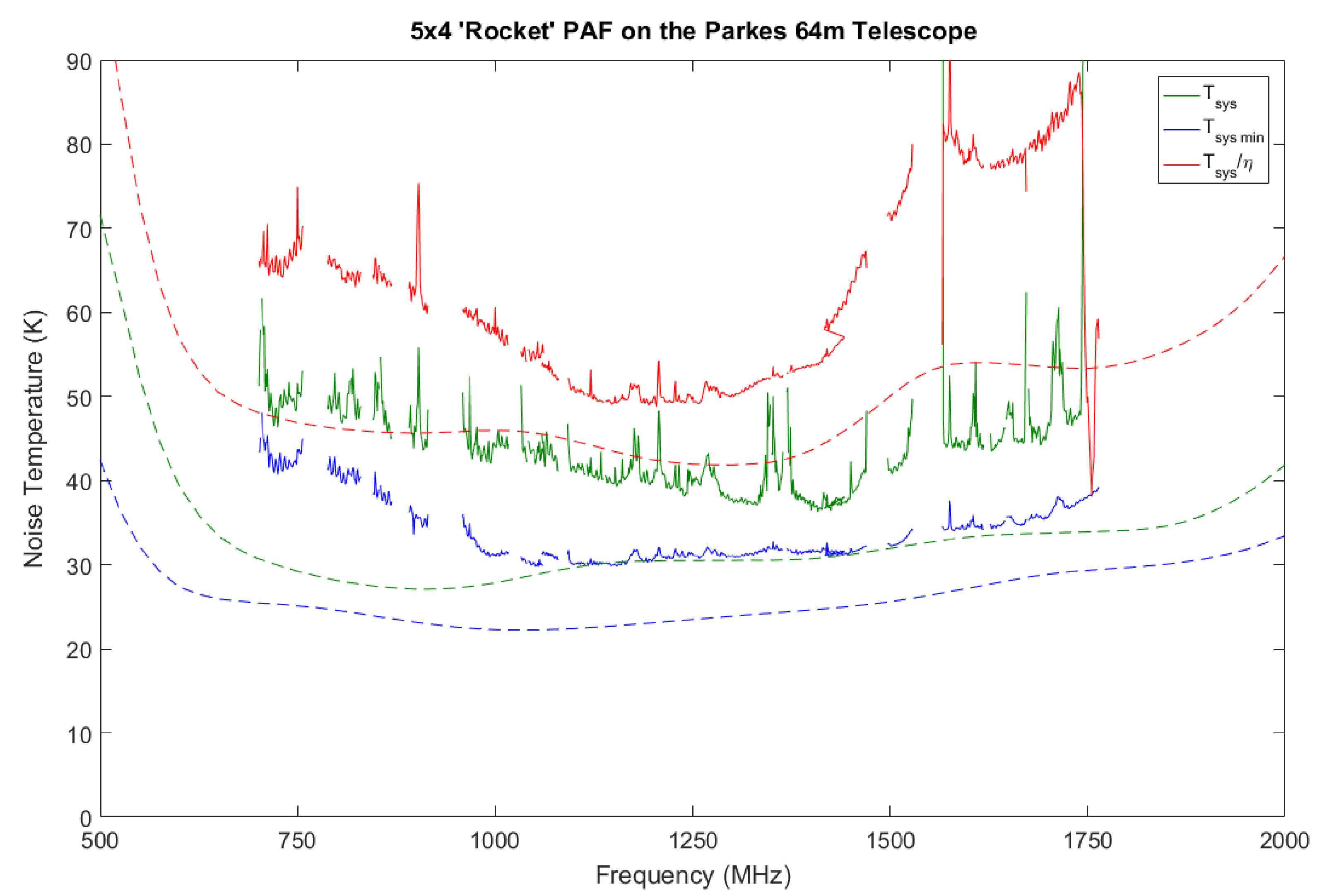
We used Virgo to derive MaxSNR beamforming weights and to measure Tsys/η

Using pyramidal absorber as a hot load and the sky as a cold load we measured the system temperature

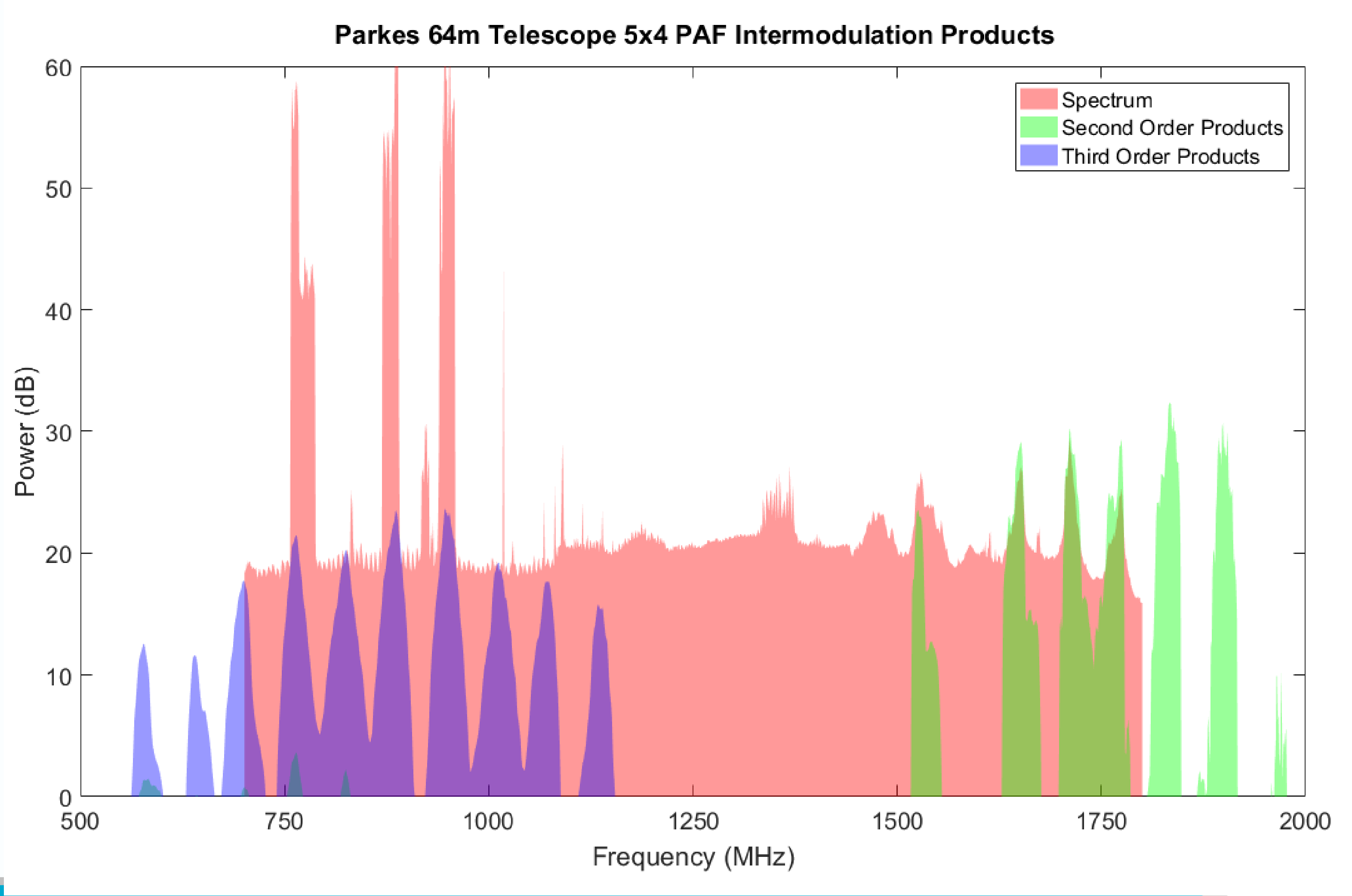
We would have liked to use an adjacent 12m antenna as a reference for holography. However due to the large delay between signals the phase wrap in the 1MHz frequency bins was too great.

A vertex radiator was used as a channel to channel calibrator.

On dish measurements



On dish measurements: Intermodulation products, the culprit?



Summary

The PAF seems to be functioning as expected in aperture array tests however more work need to be done on reconciling the on dish measurements with simulation

At the moment our major effort is aimed towards improving post LNA dynamic range in order to tolerate high levels of RFI

We aim in the near future to start working towards a cryogenic array for the Parkes telescope as well as working with a semiconductor foundry to produce custom LNA MMICs

Thank you

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