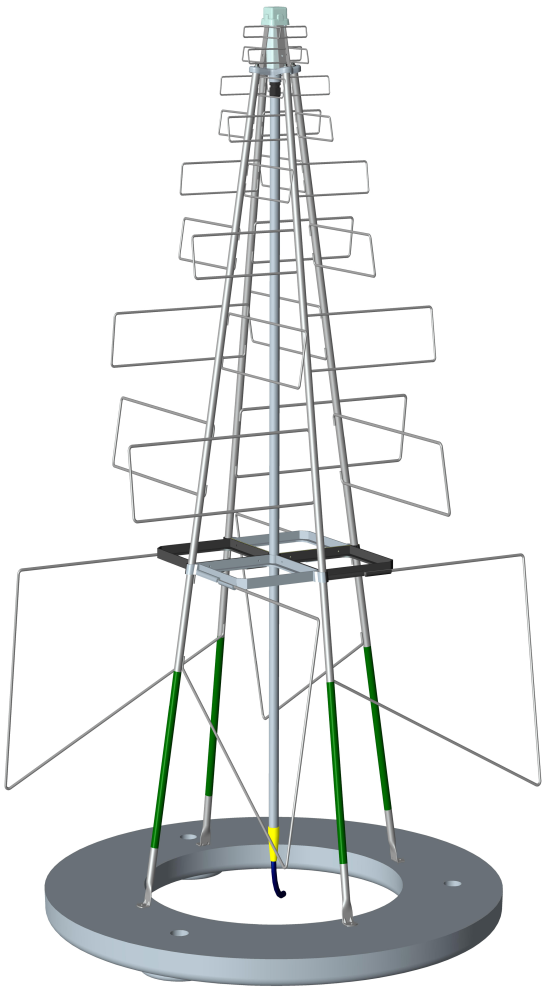
Antenna developments towards SKA1

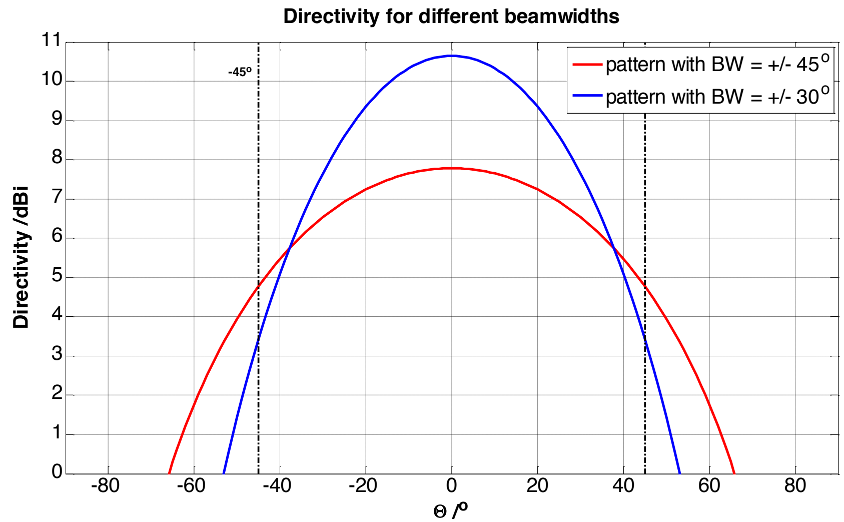
Eloy de Lera Acedo (University of Cambridge)
email: eloy@mrao.cam.ac.uk

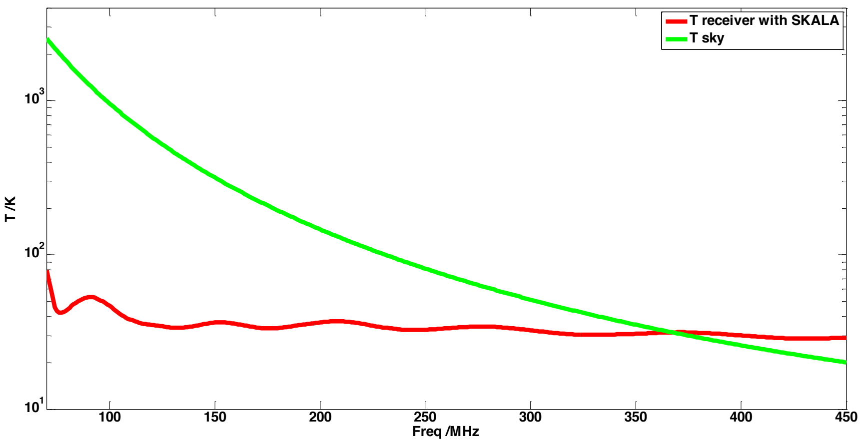
Overview

- SKALA2; AAVS1 antennas
- Frequency ripple in SKALA2
  - Current version
  - Optimization against science requirements
  - Update on the solution (SKALA3)
- Conclusions

Recap: Array element design

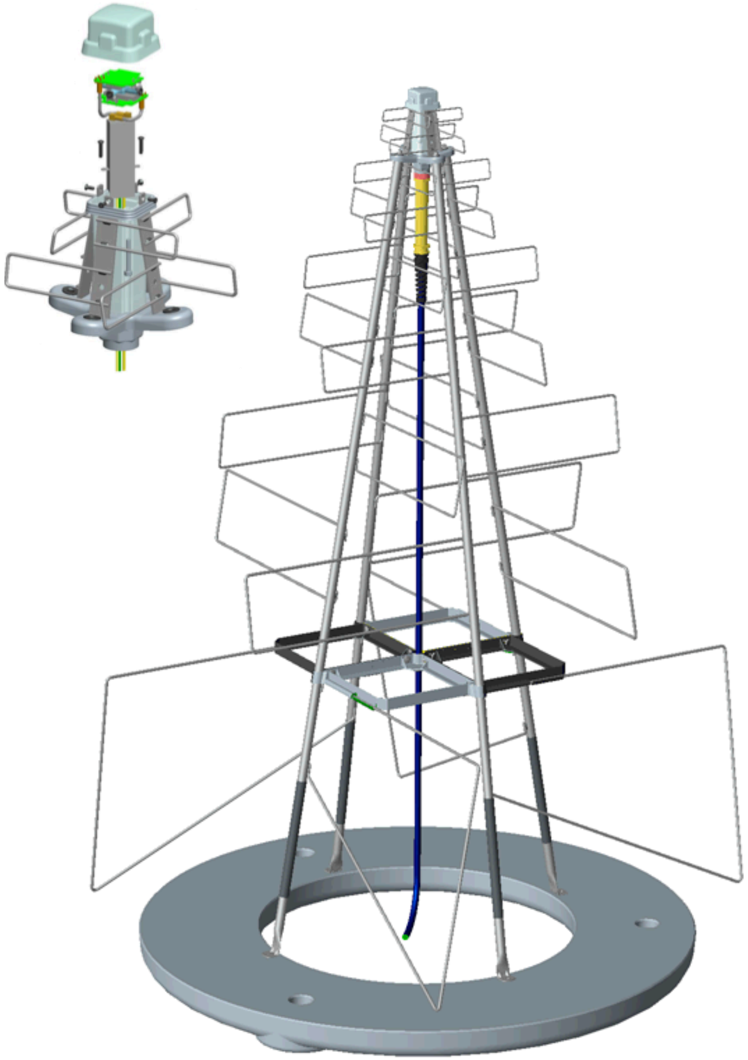


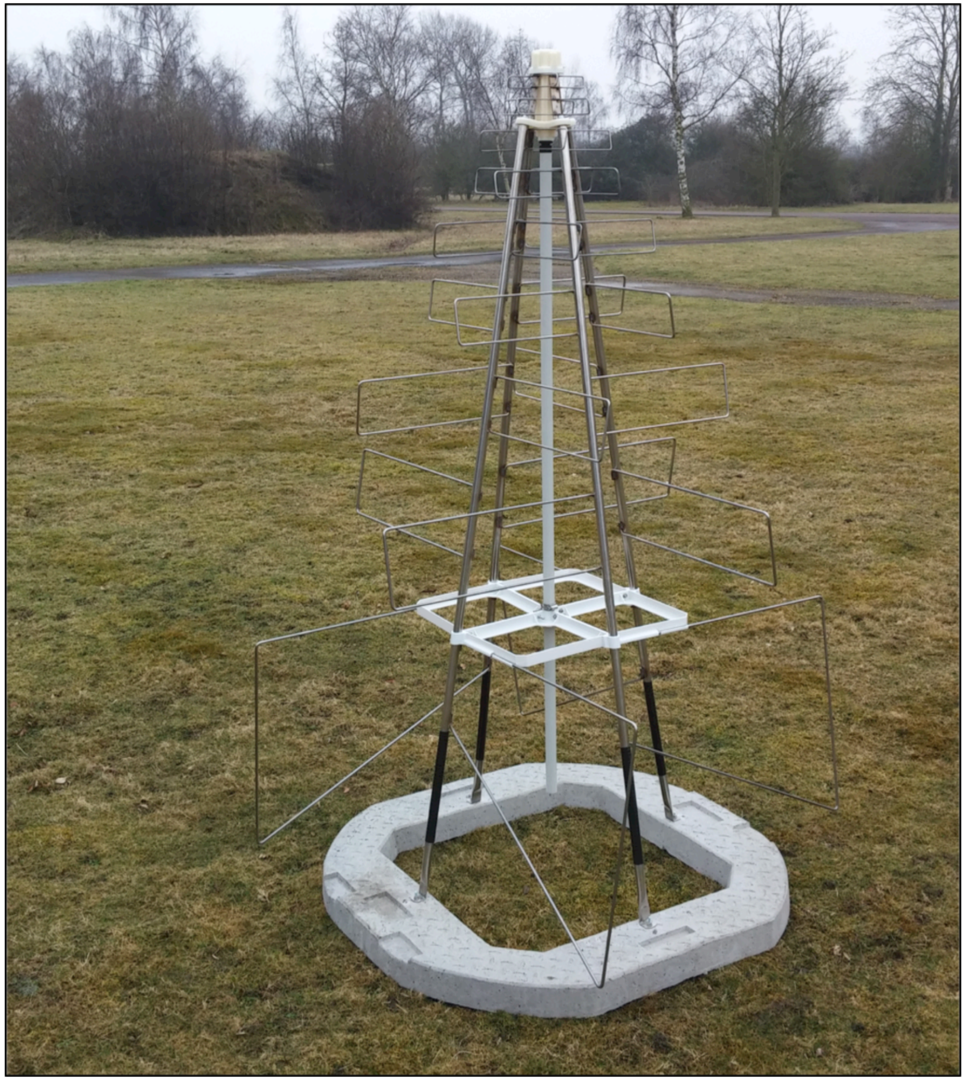




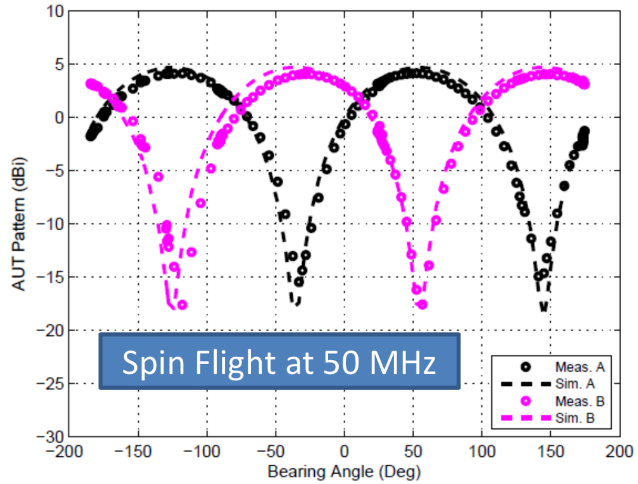
SKALA1: EXPA 2015, *de Lera et al.

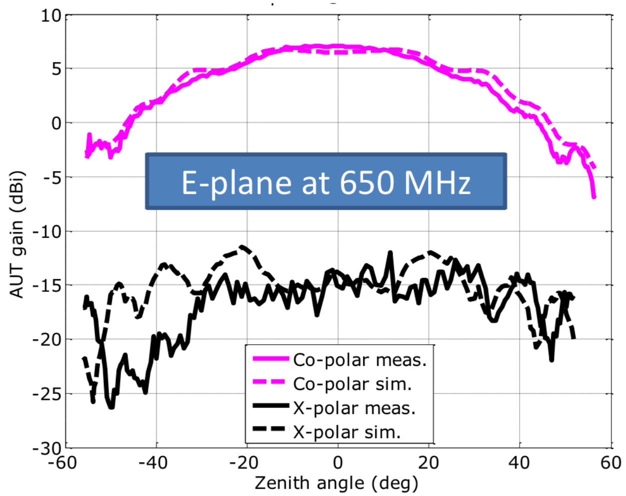
SKALA2





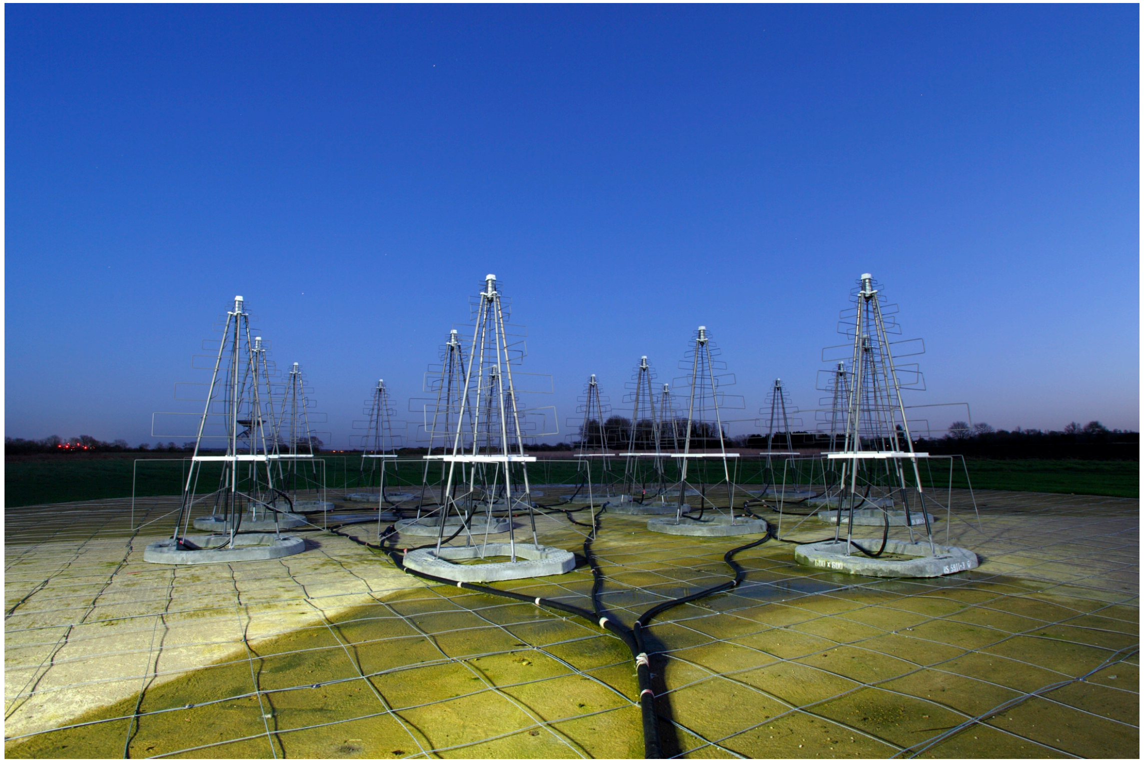
SKALA2 + LNA latest tests

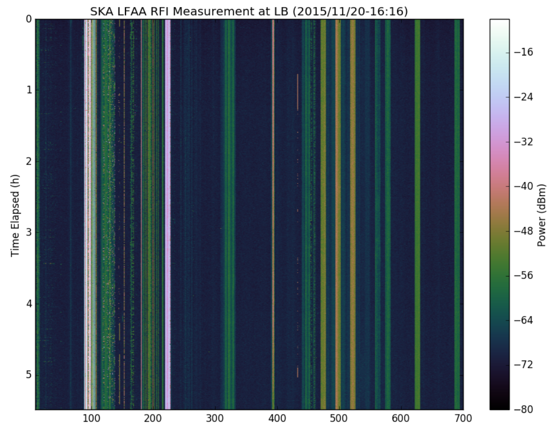


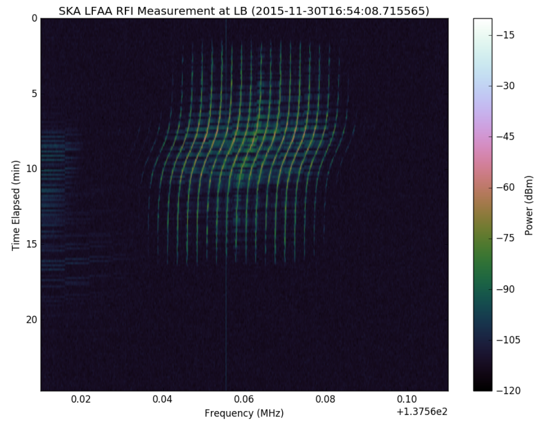


SKALA2 + LNA latest tests

Pre-AAVS1 @ Cambridge



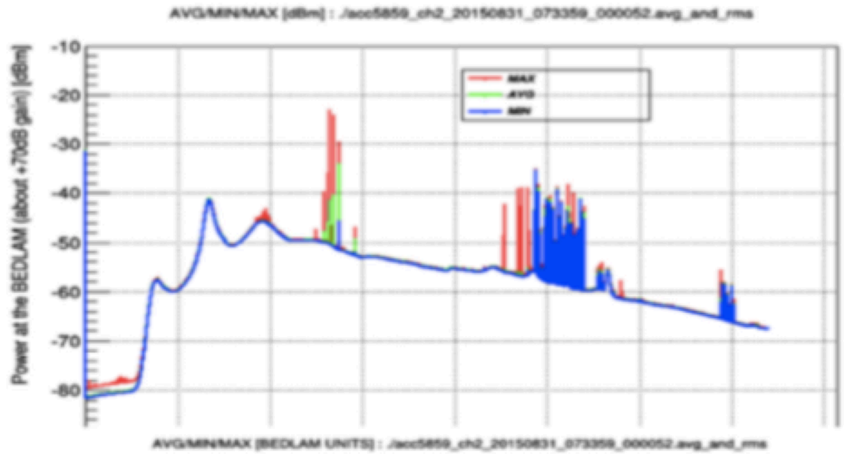




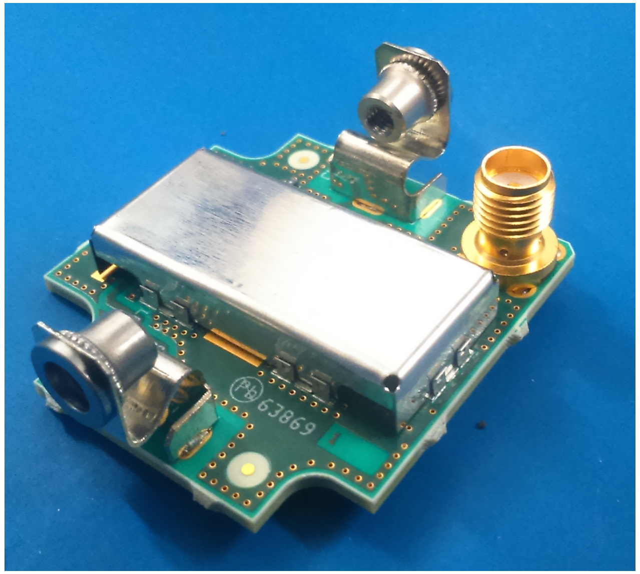
SKALA2 @ MRO

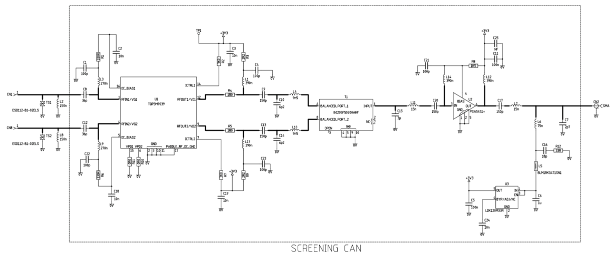
*Credit: Randall Wayth, ICRAR

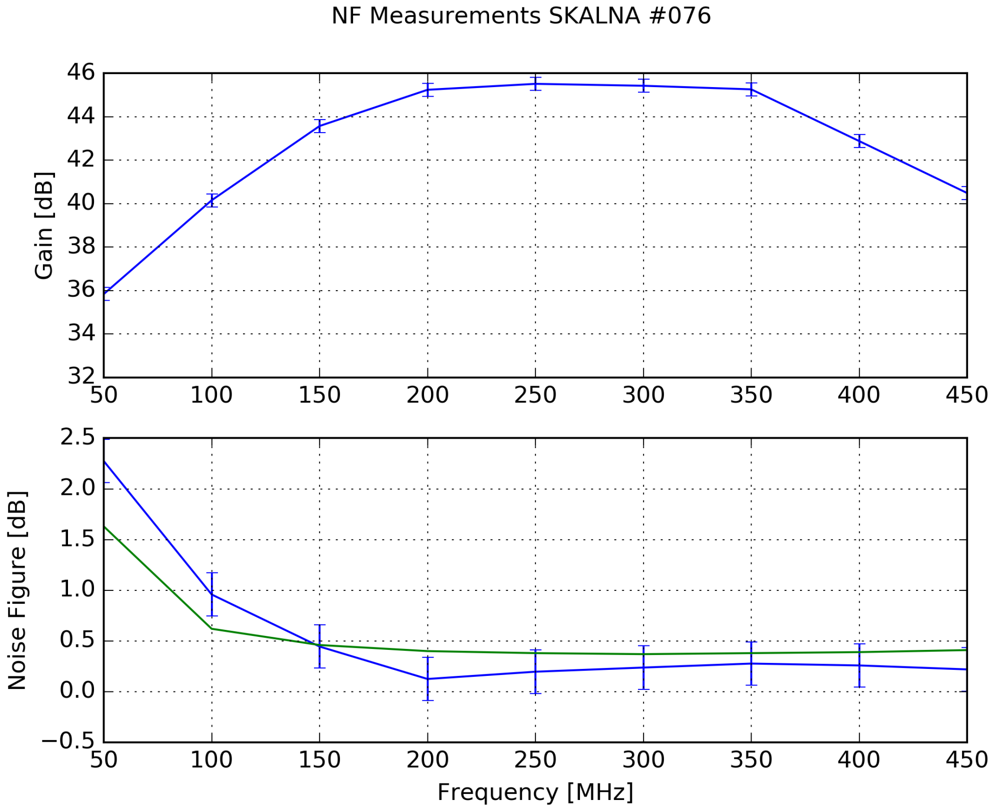
10_350_MHz_totalpower_DBM.max_power



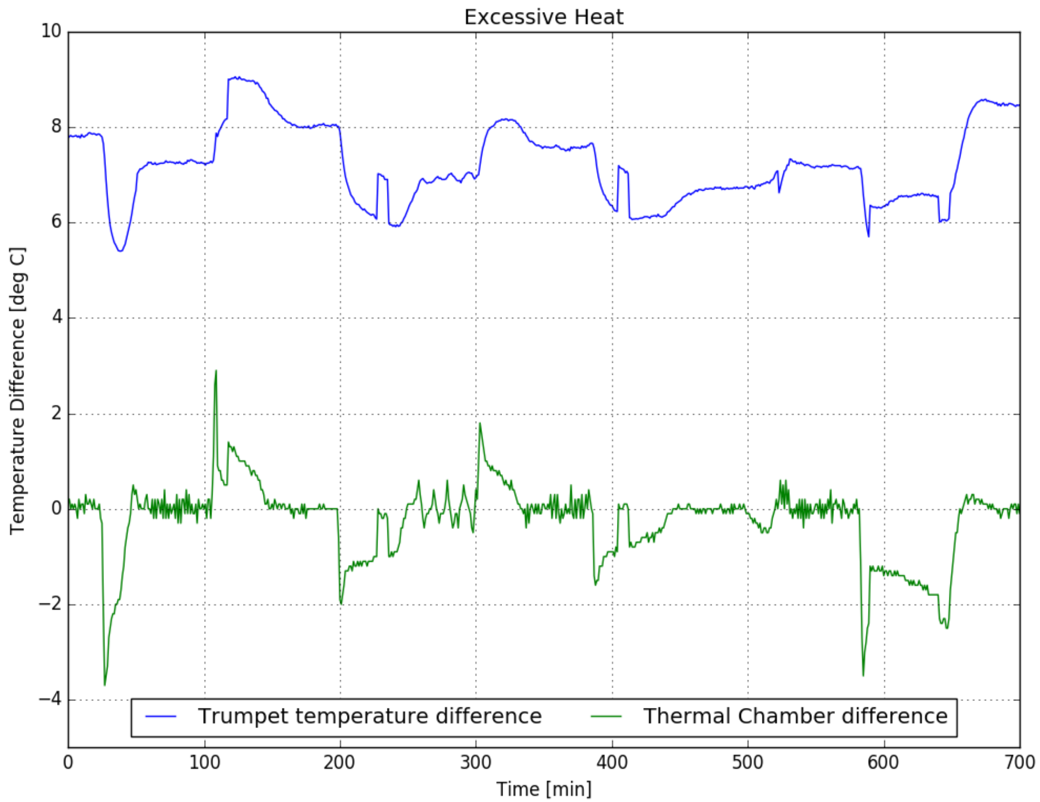
SKALA2 + LNA latest tests



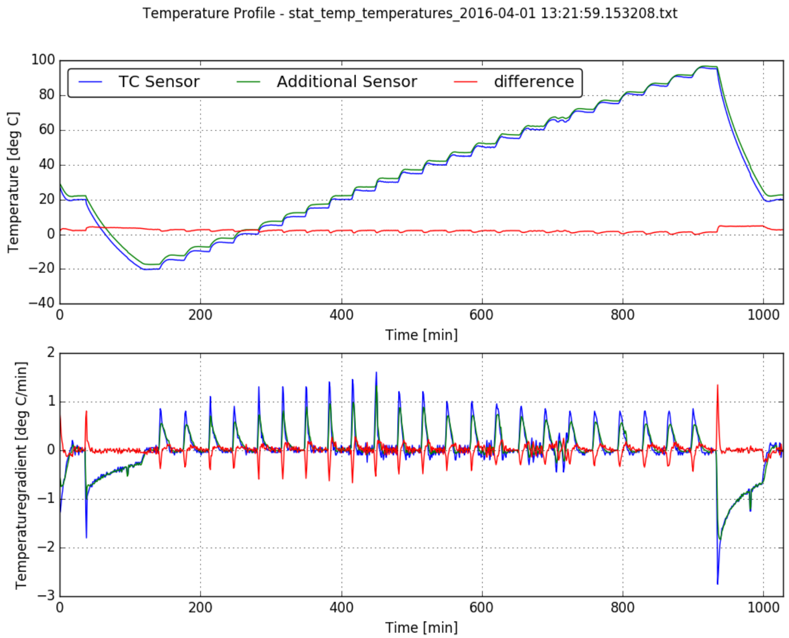


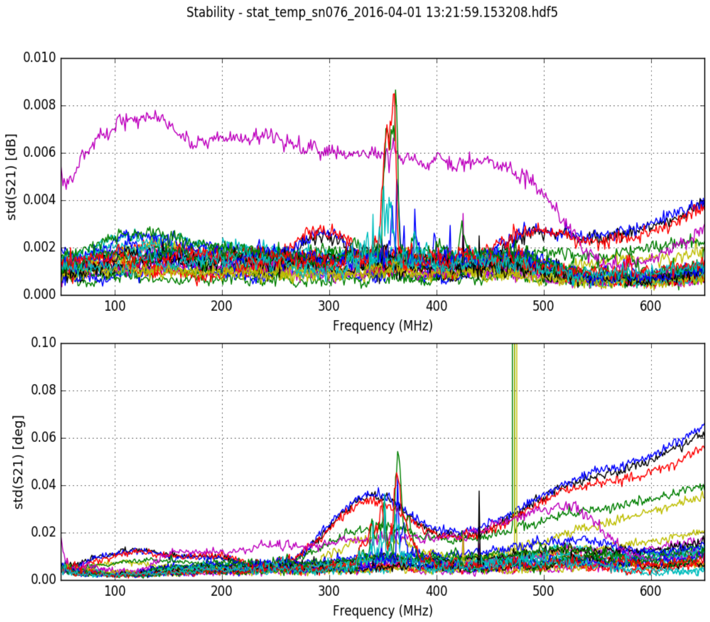


SKALA2 + LNA latest tests



SKALA2 + LNA latest tests





Lowest L3 requirement:

0.17 dB and *1.2°*

Frequency ripple in SKALA2

LNA

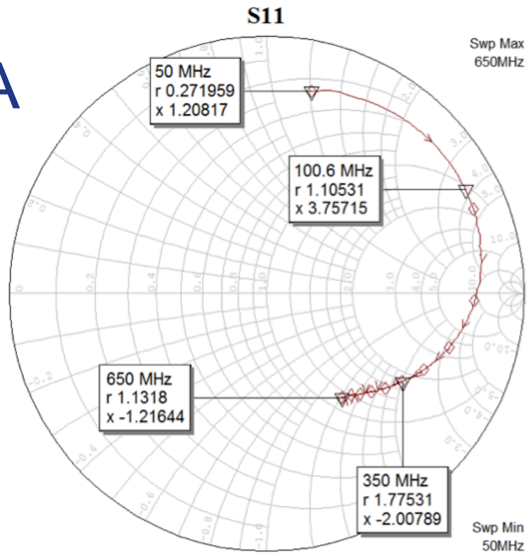
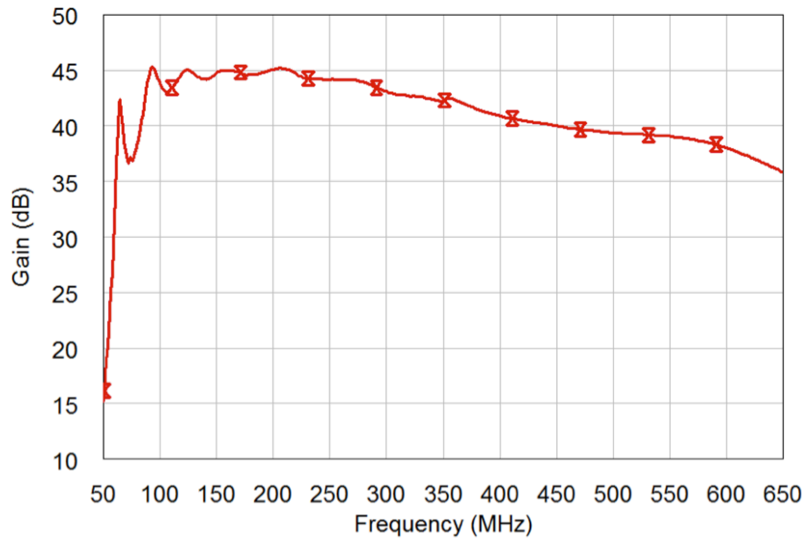


Fig. 5. LNA S_{11} in isolation including input network



Antenna

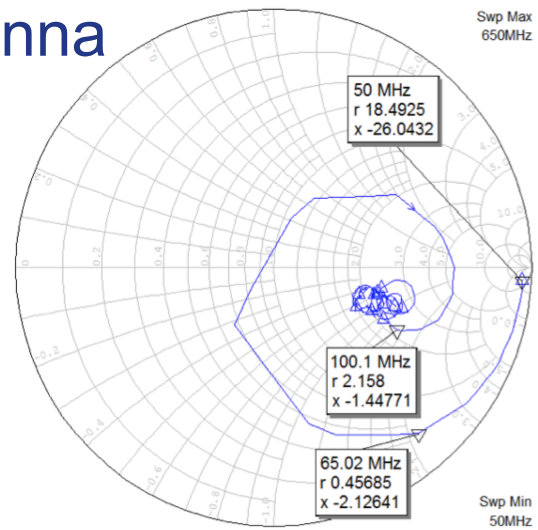
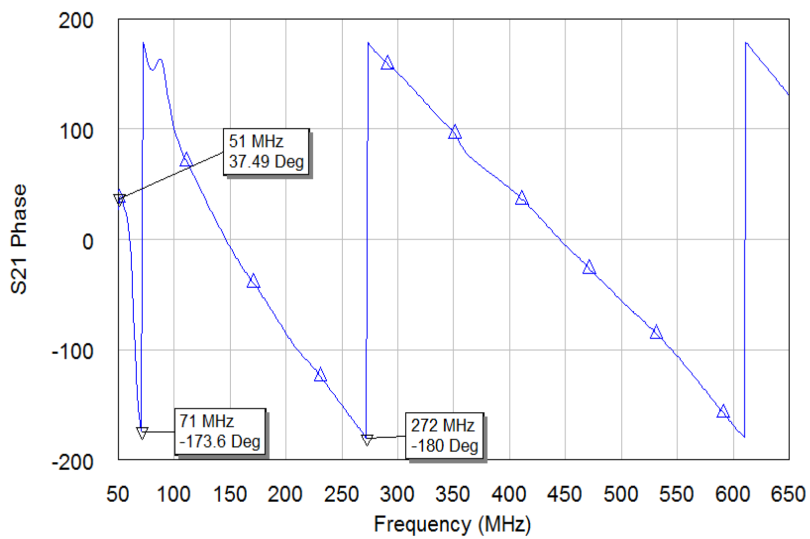
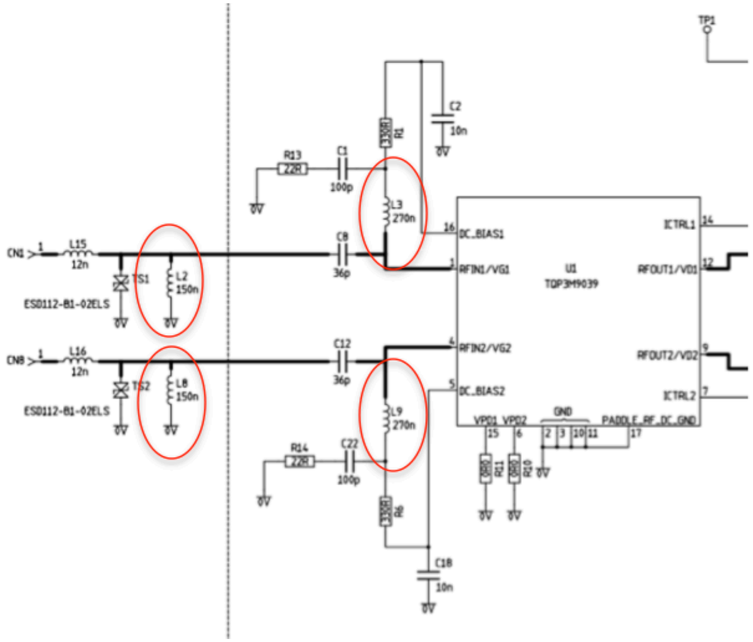


Fig. 6. Original antenna impedance as measured at Lord's Bridge

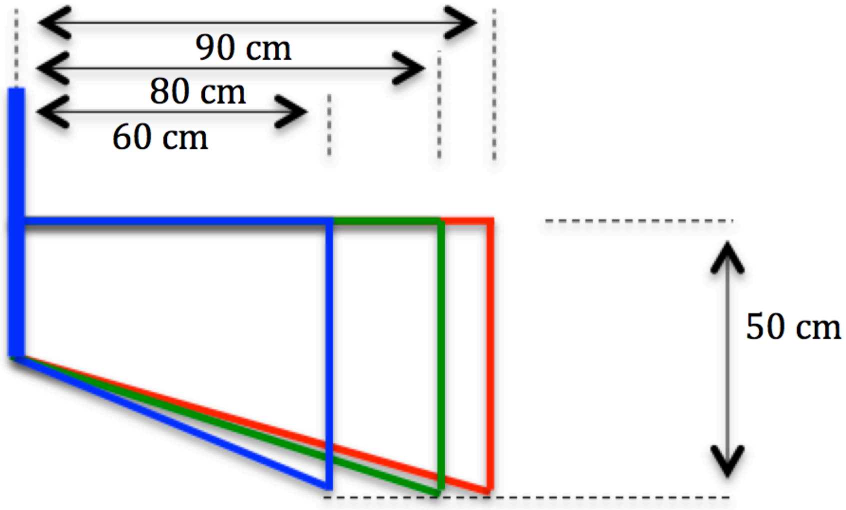


Initial optimization work

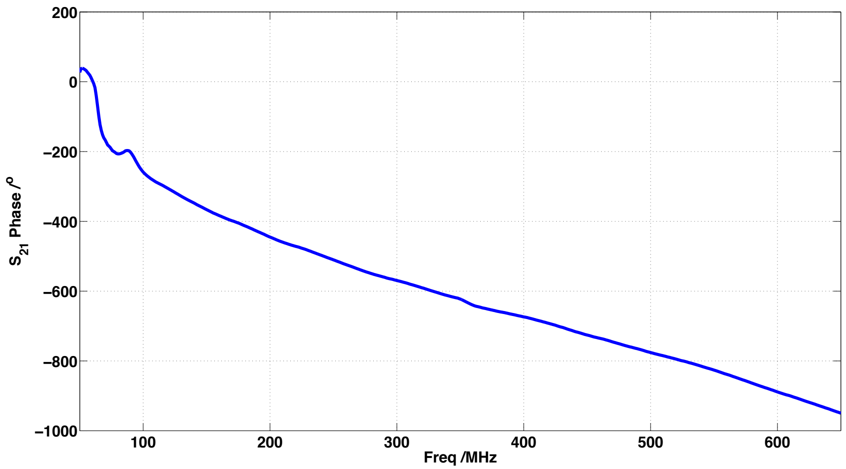
LNA

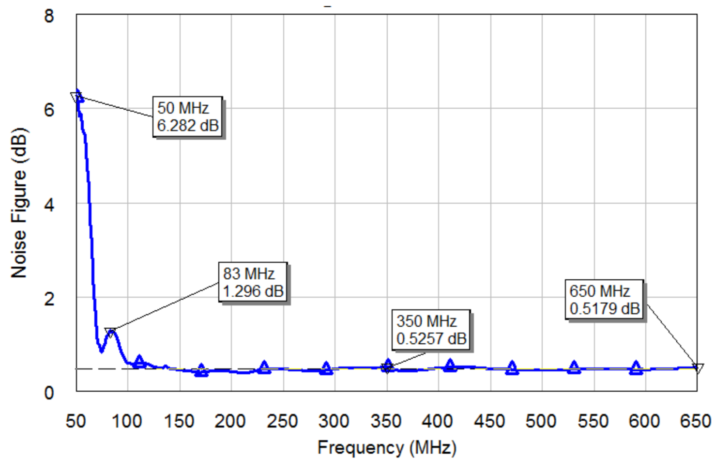


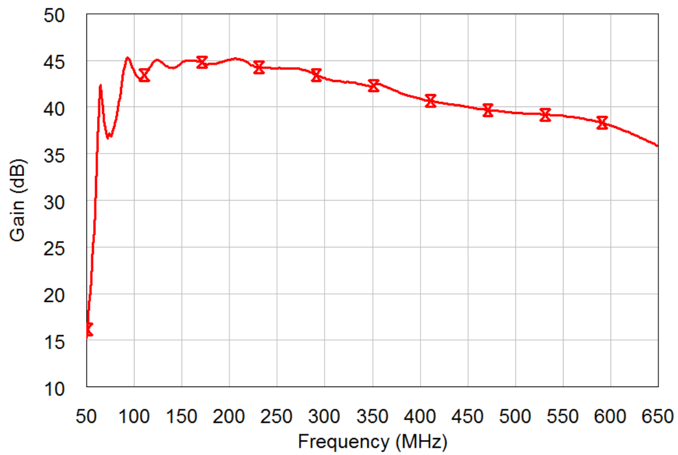
Antenna



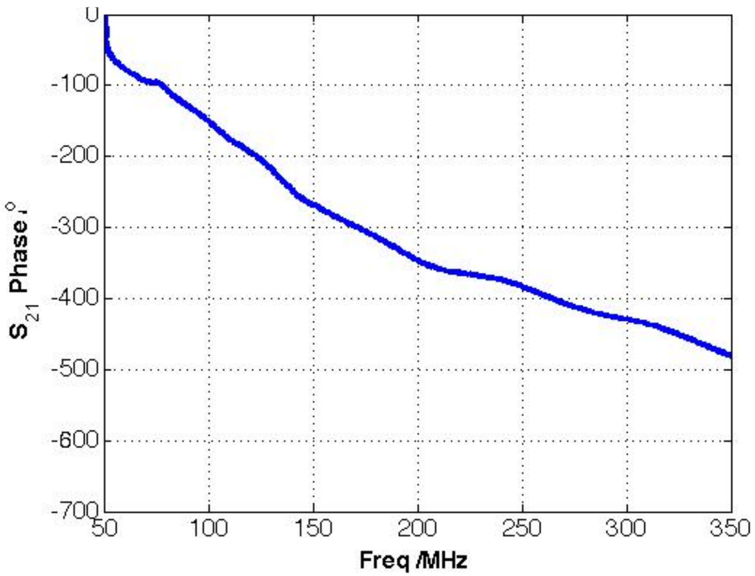
Current


200
0
−200
−400
−600
−800
−1000
100
200
300
400
500
600
Freq /MHz
S_{21} Phase /°

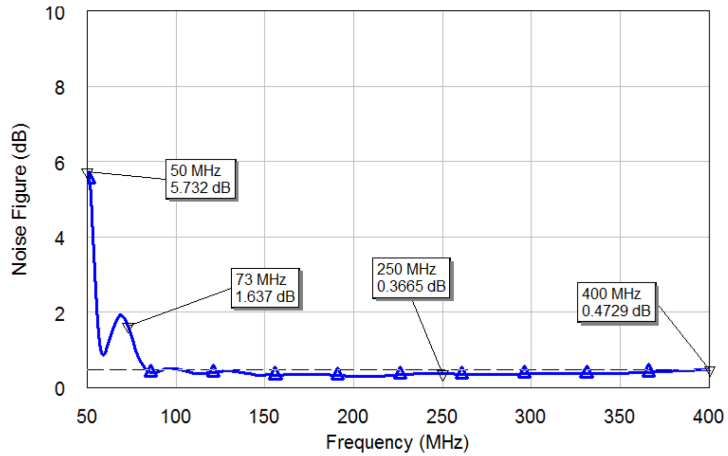

8
6
4
2
0
Noise Figure (dB)
50 MHz
6.282 dB
83 MHz
1.296 dB
350 MHz
0.5257 dB
650 MHz
0.5179 dB
50 100 150 200 250 300 350 400 450 500 550 600 650
Frequency (MHz)


50
45
40
35
30
25
20
15
10
Gain (dB)
50 100 150 200 250 300 350 400 450 500 550 600 650
Frequency (MHz)

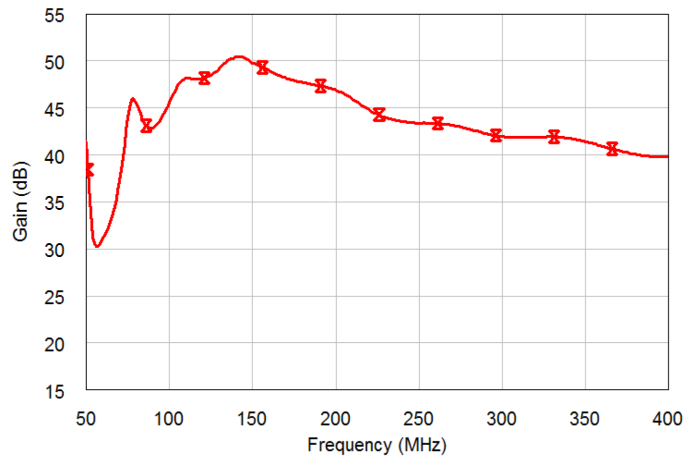
Optimized



0
-100
-200
-300
-400
-500
-600
-700
50
100
150
200
250
300
350
Freq /MHz
S21 Phase °



Noise Figure (dB)
Frequency (MHz)
50 MHz
5.732 dB
73 MHz
1.637 dB
250 MHz
0.3665 dB
400 MHz
0.4729 dB



Gain (dB)
Frequency (MHz)

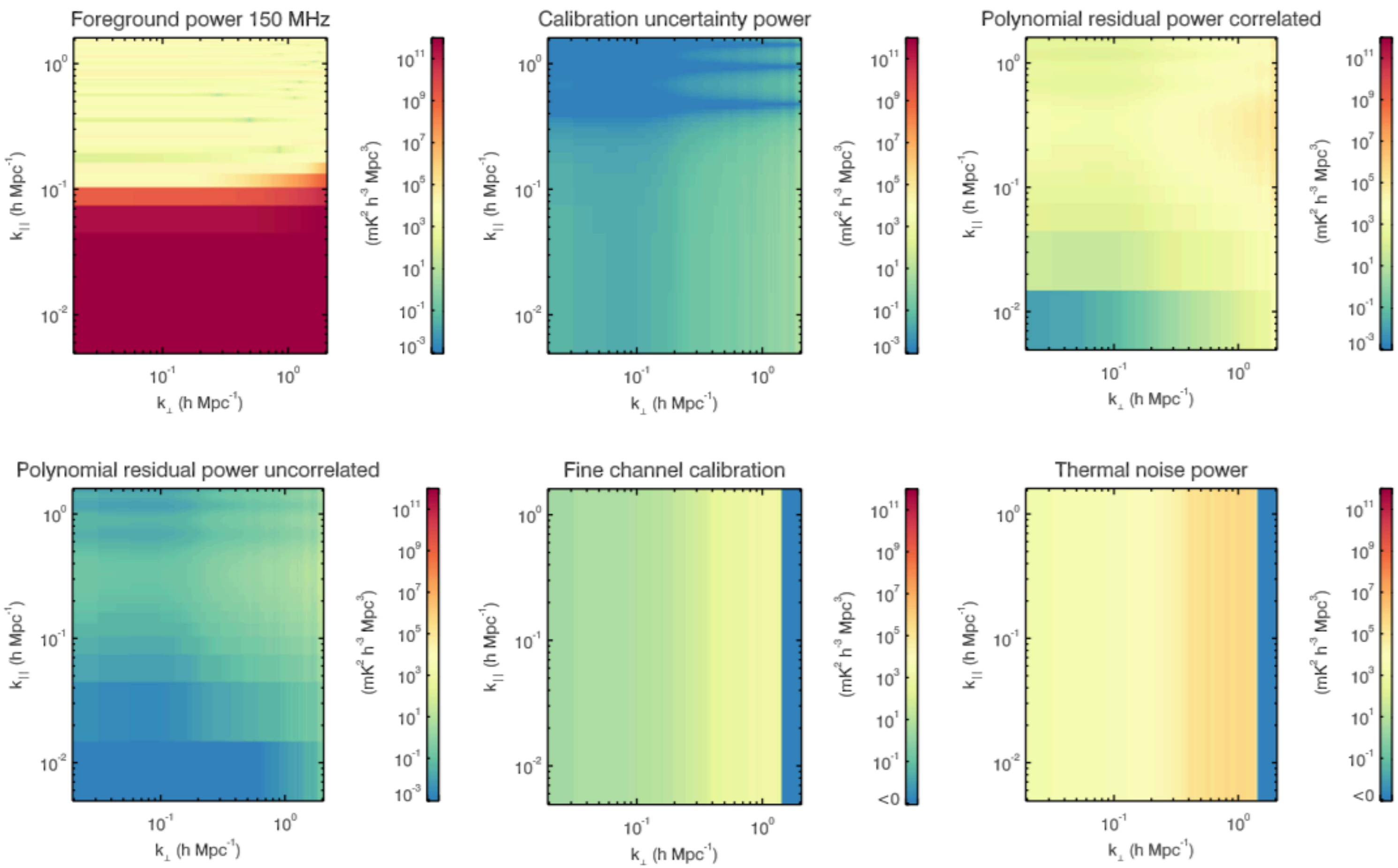
Foundation of the requirements

- No L1 requirements. Based on discussions with the SKAO, the SKA-LOW Science groups and LOFAR and MWA experts.
- Based on the "Spectral calibration requirements of radio interferometers for Epoch of Reionisation science with the SKA" (*Trott, Wayth, PASA 2016*).
- The target is that the "power introduced by deviations from the station beam calibration model will remain below the thermal (statistical) noise power."
- Passband smoothness requirement based on fitting low order polynomials locally for the calibration (order 3 over 3 or so coarse channels).

Frequency /MHz	δ
50	0.018
100	0.01
150	0.0054
200	0.0056

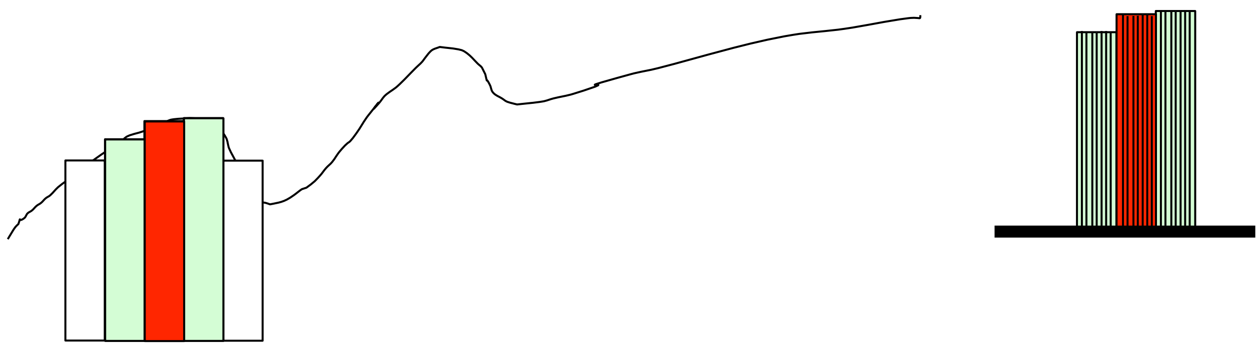
Foundation of the requirements

- **Trott, Wayth, PASA 2016.*

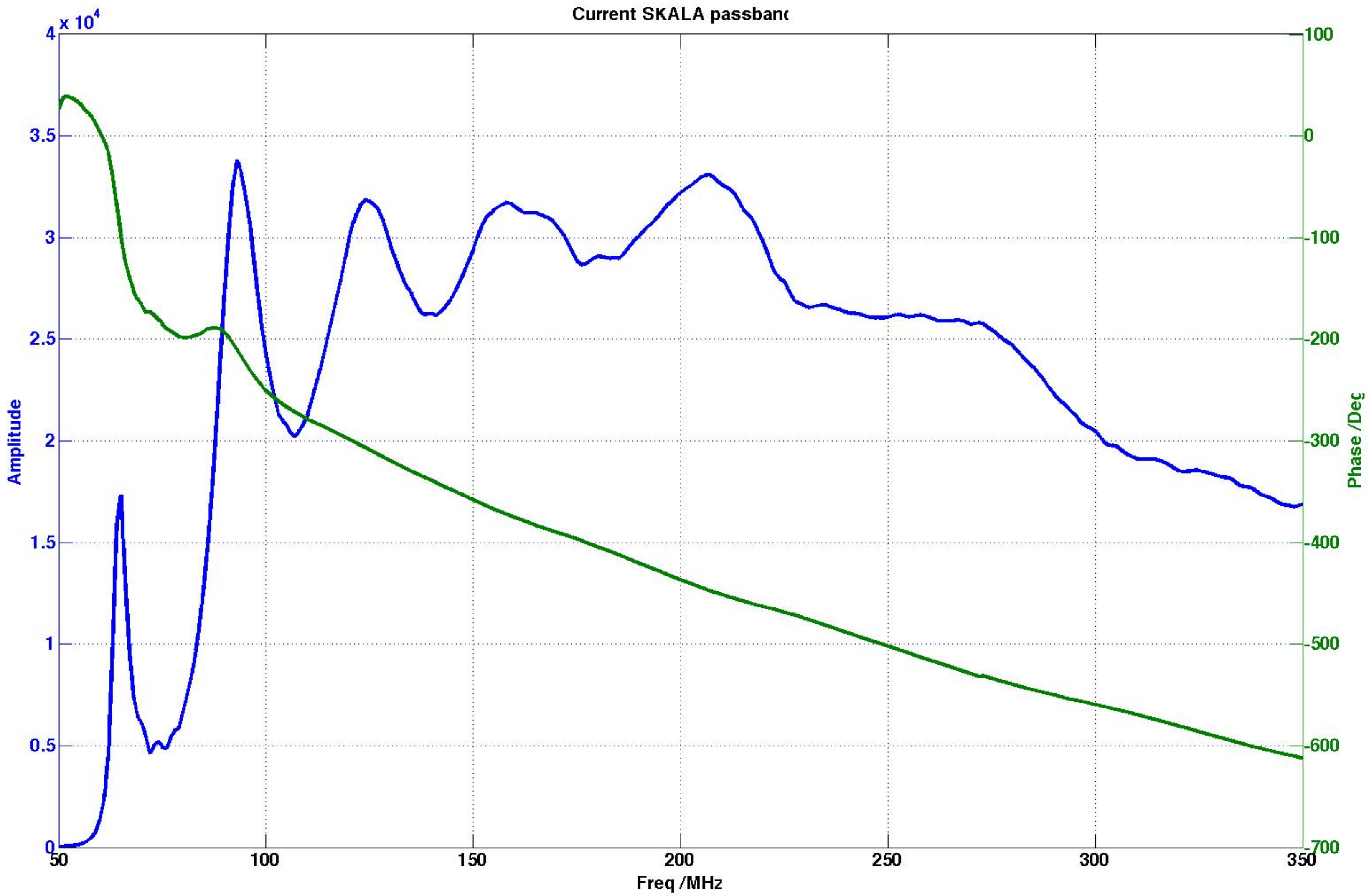


Pass-band calibration

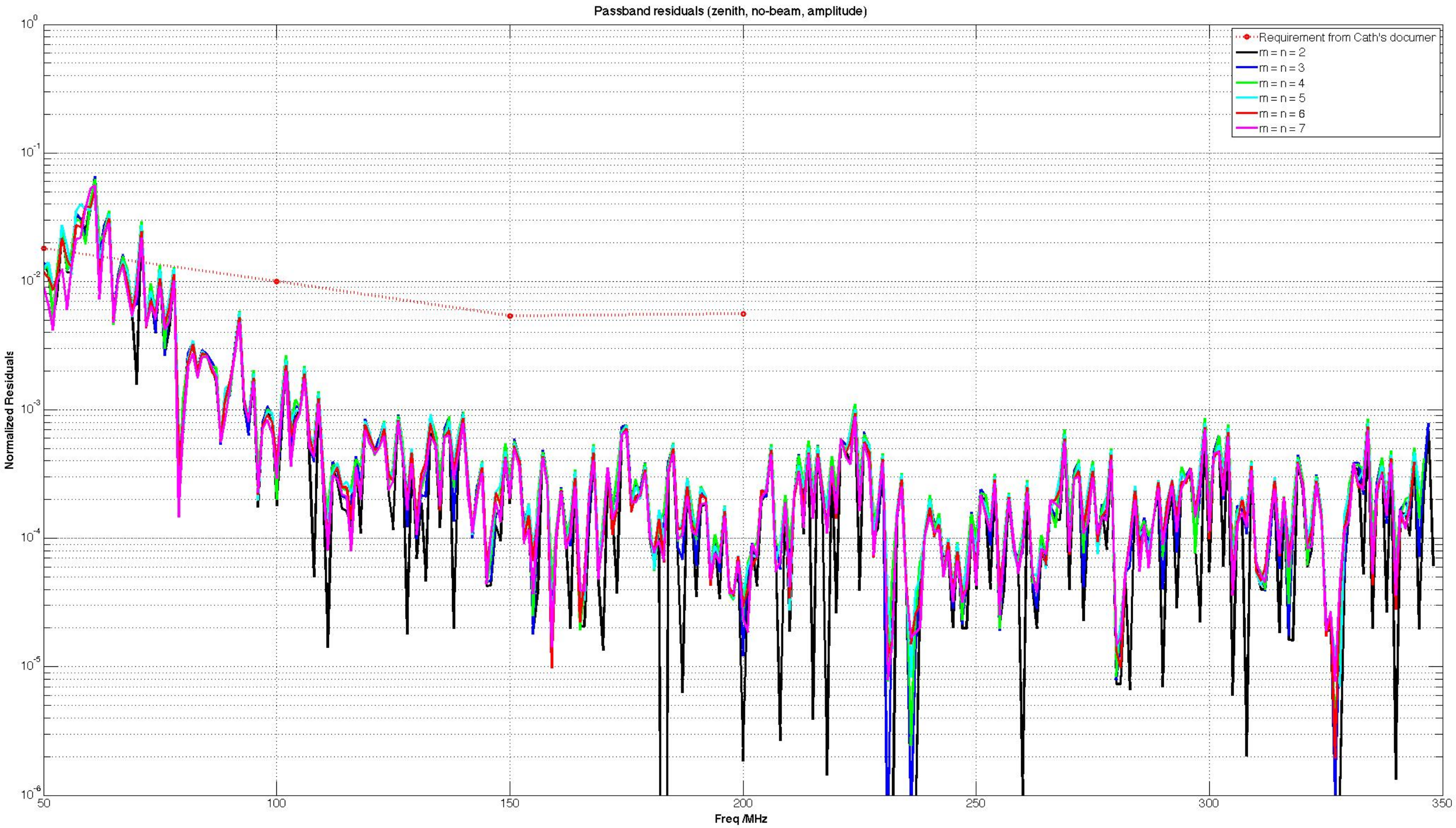
- Based on fitting a low order polynomial to a few coarse channels.
- In this presentation (similar to Comoretto 2016 and Troth 2015) the default is:
  - 3rd order polynomial
  - Using 3 coarse channels (1 channel = 750 KHz) for the fitting of the middle one.
  - 196 fine channels per coarse channel.



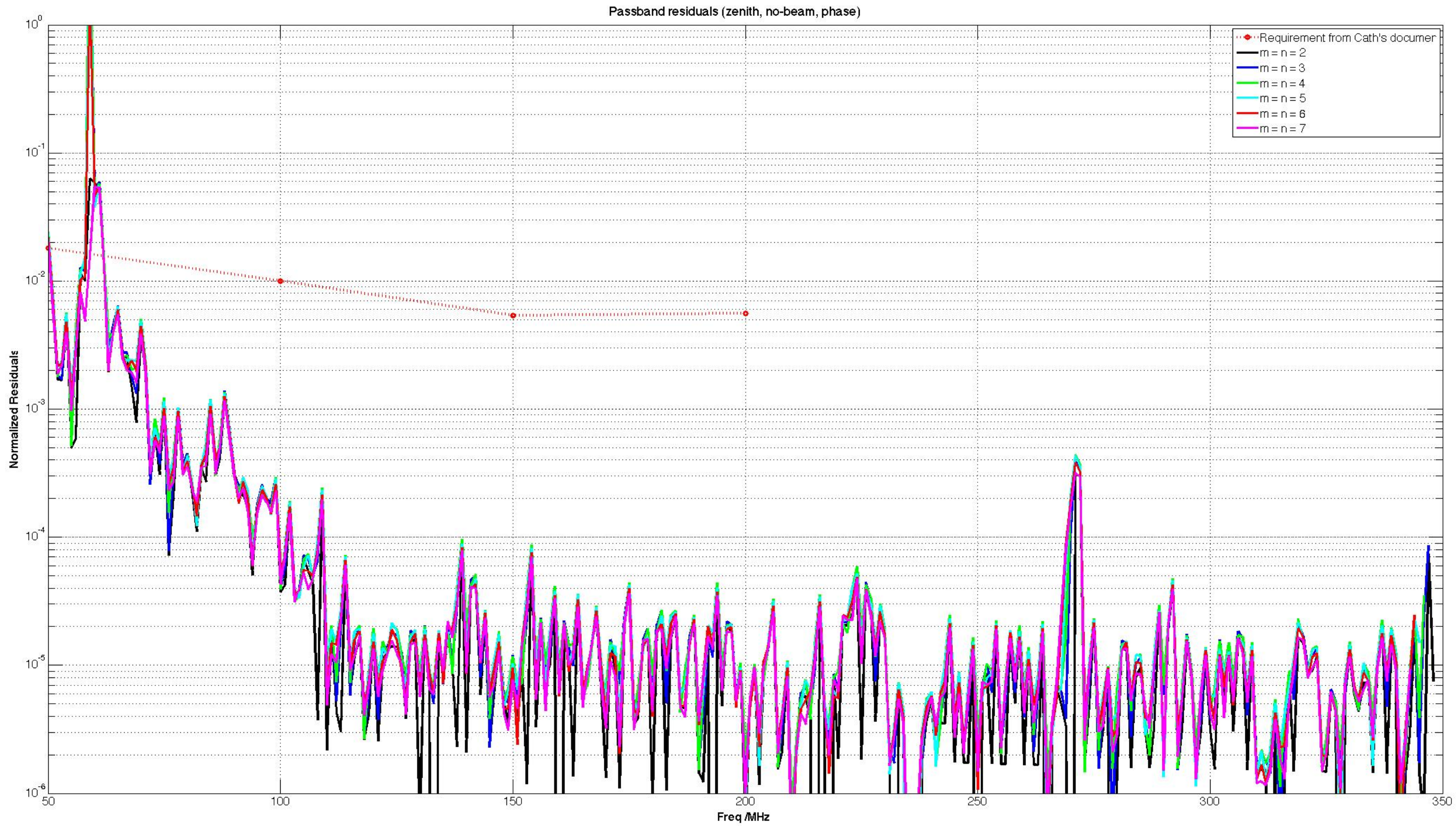
Current analysis of the residuals



Current analysis of the residuals (amplitude)

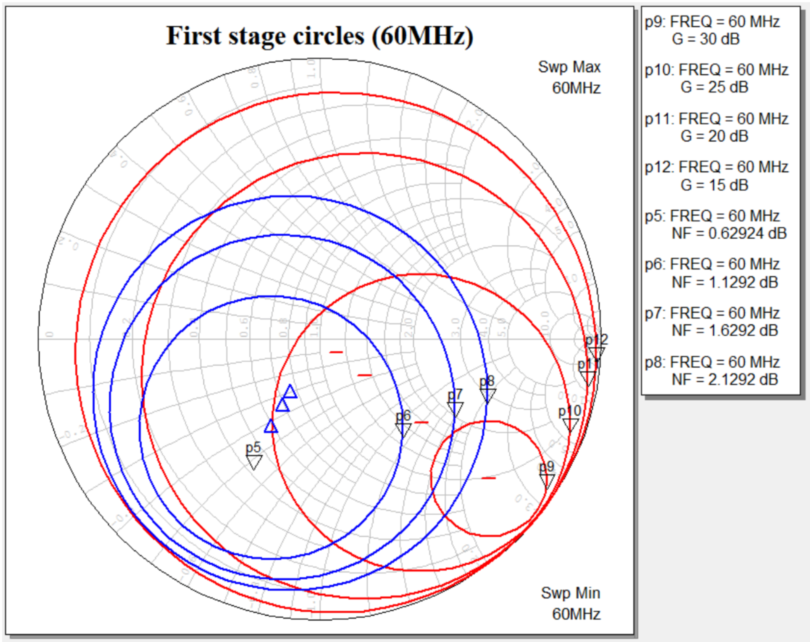


Current analysis of the residuals (phase)

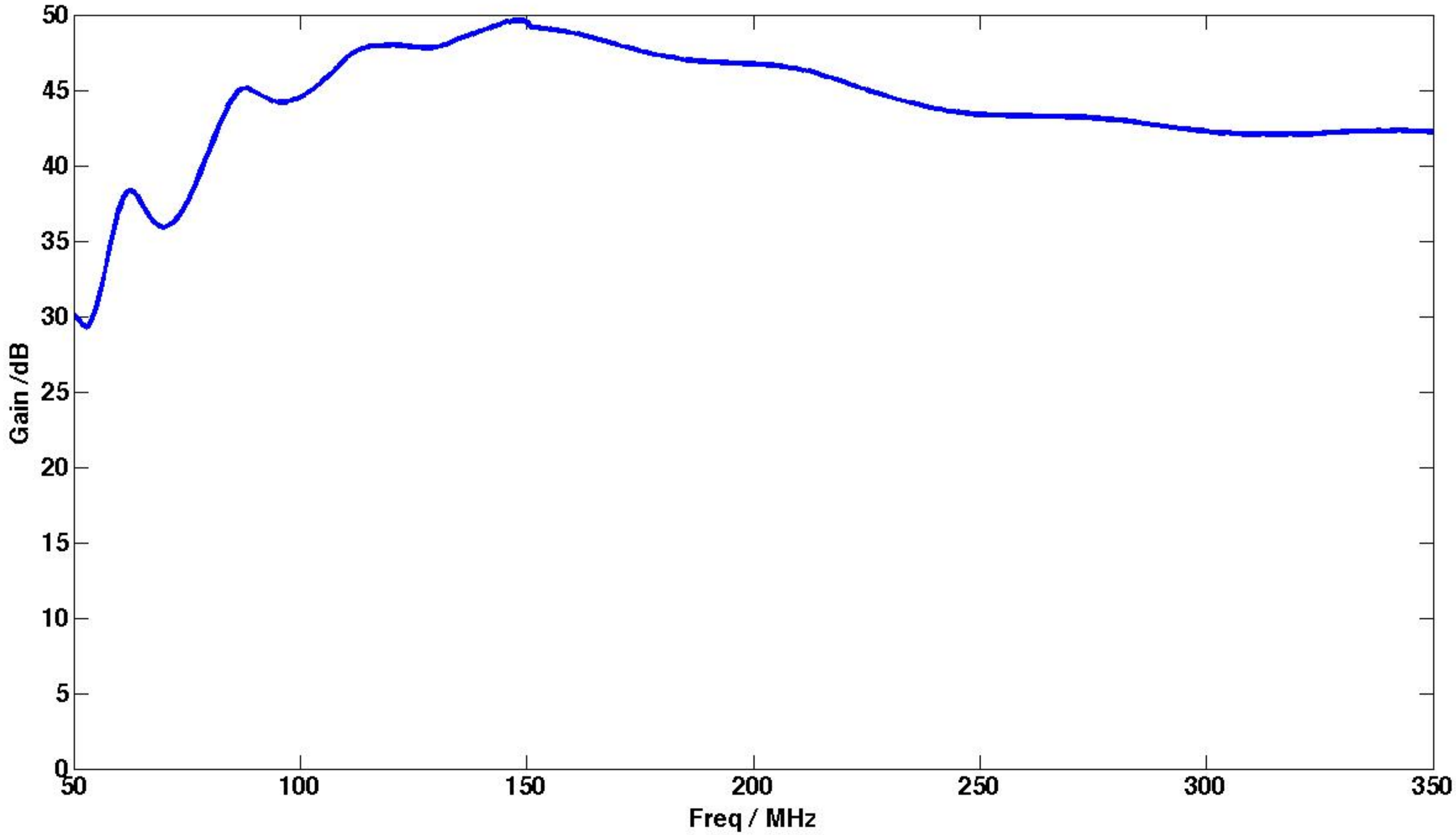


Update on the solution (SKALA3)

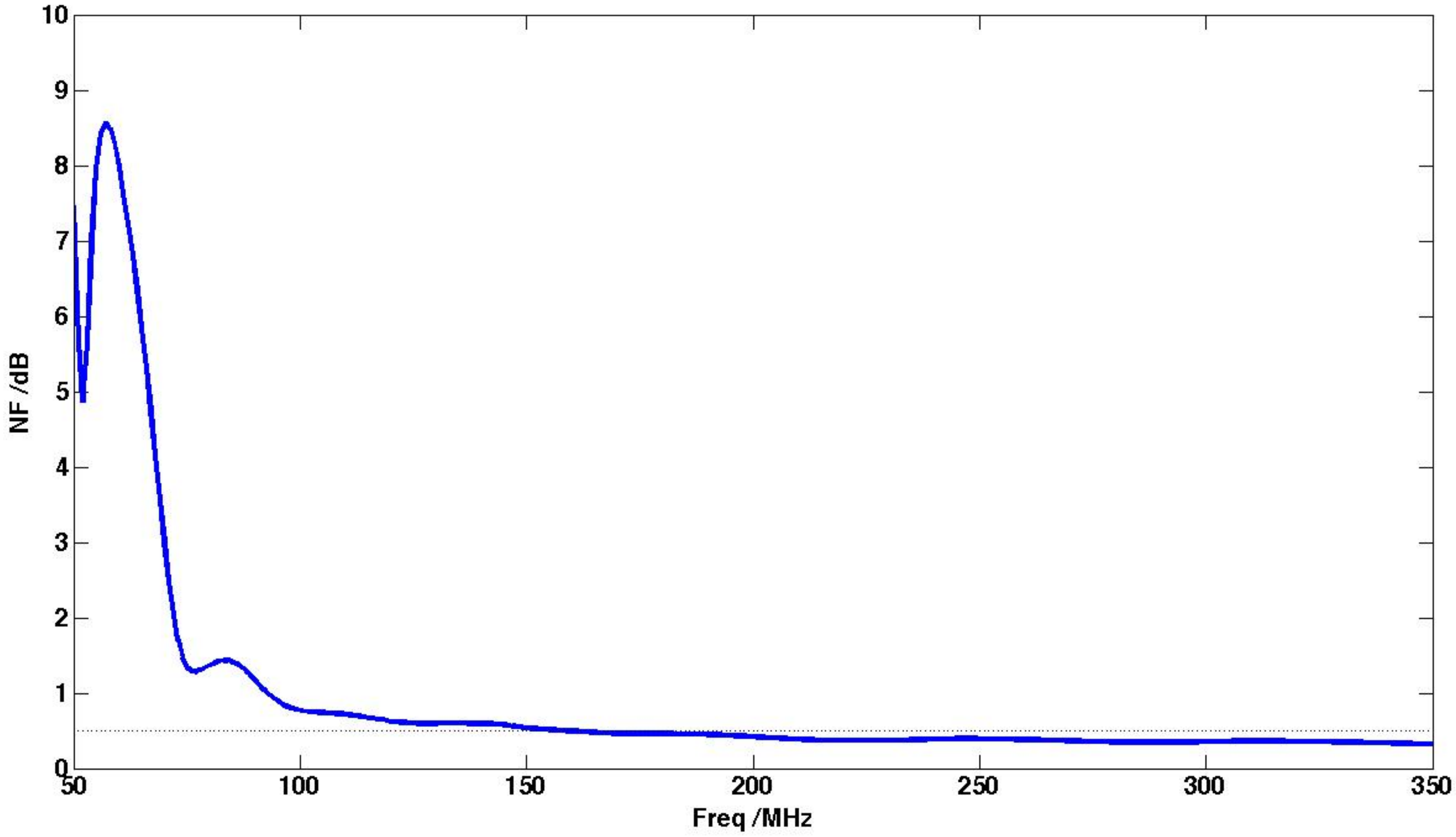
- Increased impedance of antenna (larger bottom arm)
  - 1.6x1.6 m footprint
  - Incidentally: better polarization response, better slow-ripple across band.
- Tuned input network of LNA (reduced series capacitance – 24 pF)



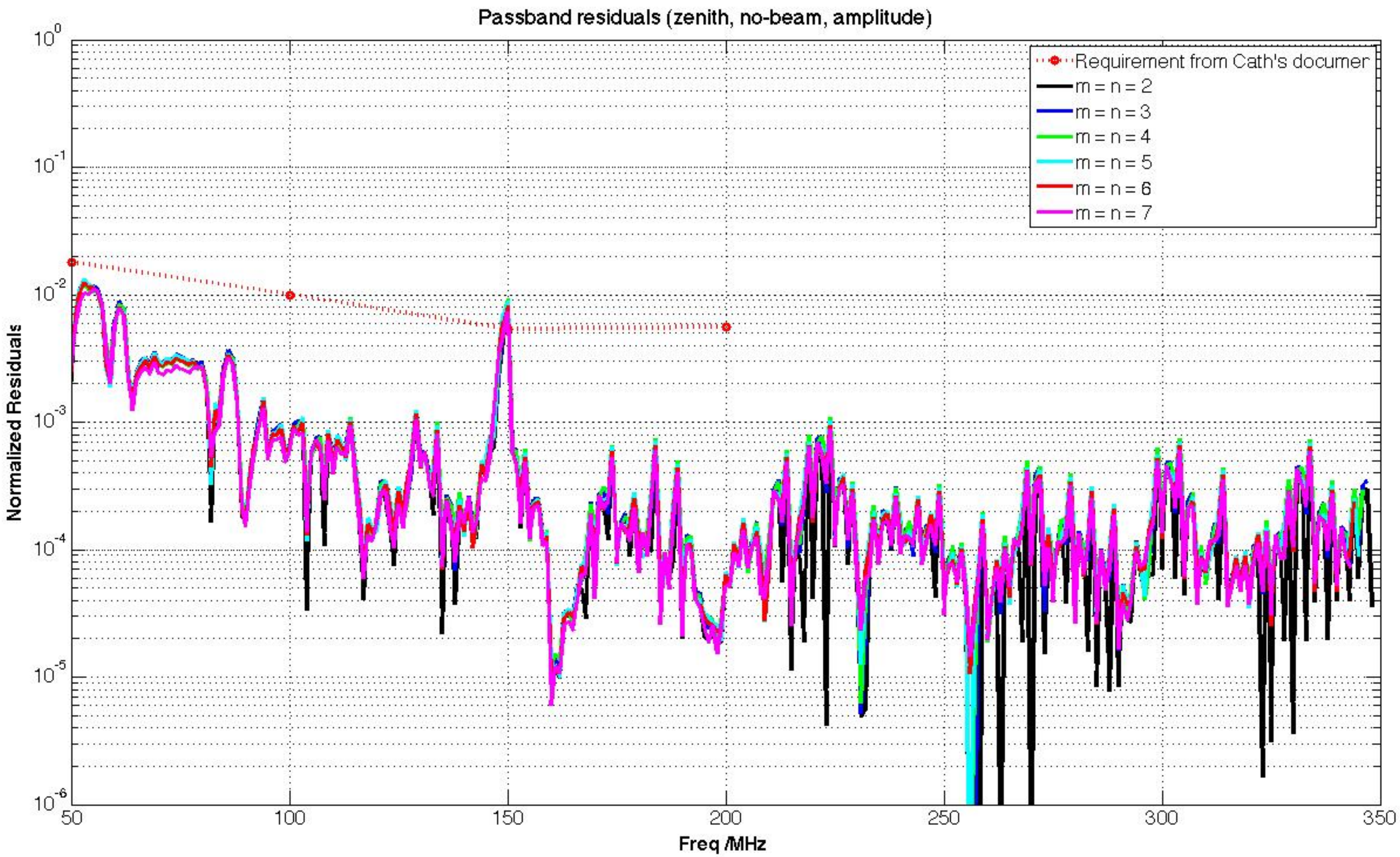
Update on the solution (SKALA3)



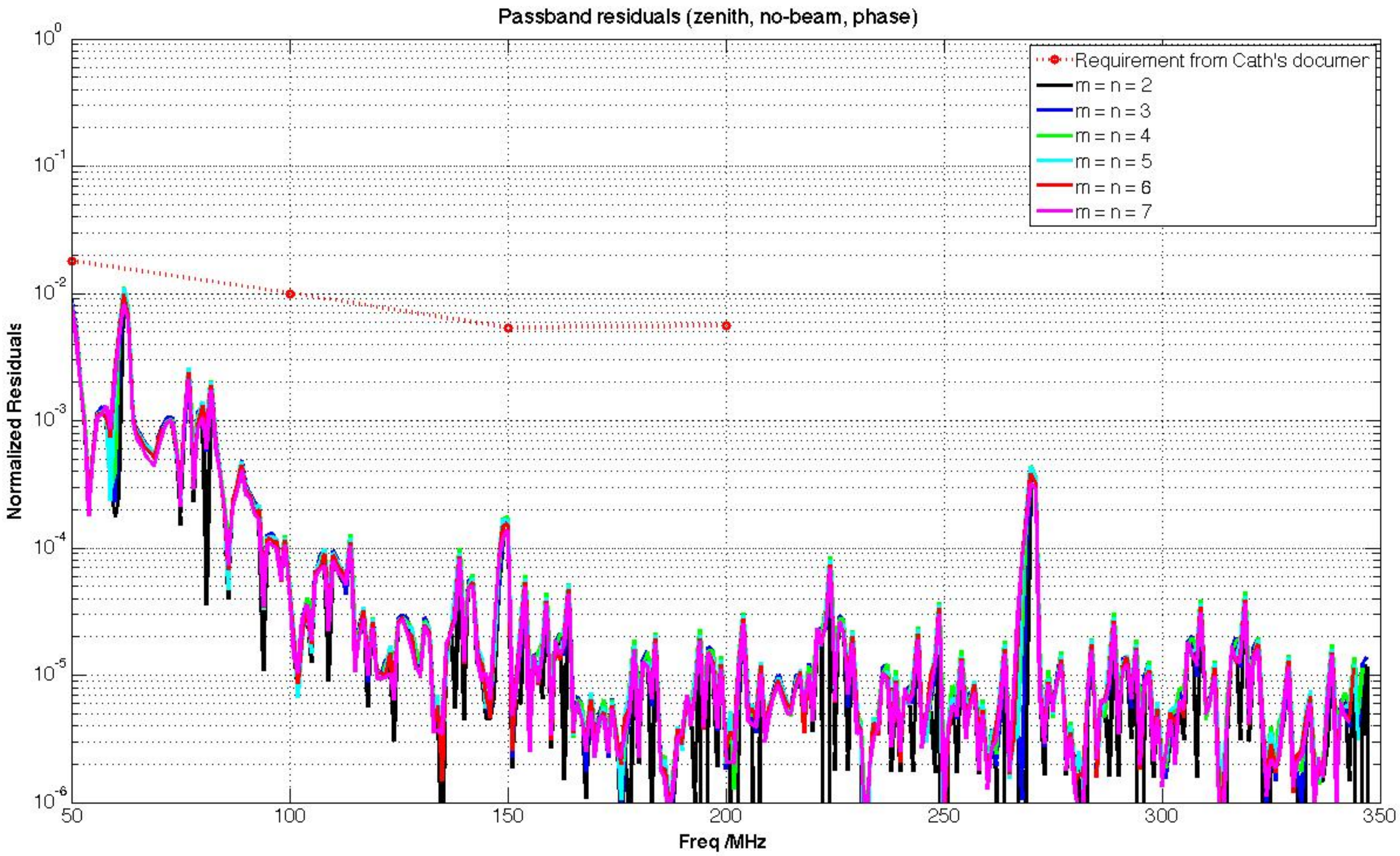
Update on the solution (SKALA3)



Update on the solution (SKALA3)



Update on the solution (SKALA3)



Next steps

- On the analysis:
  - Inclusion of polarization effects and DDEs.
  - OSKAR simulations.
- On the antenna design:
  - Converge into a satisfactory solution (summer 2016). Can we improve further by:
    - Increasing the number of dipoles and their frequency spacing?
    - Tuning the spine angles and dipole lengths?
    - Tuning the antenna length?
    - Further tuning on LNA input network.
  - Build of prototypes to test in isolation and with Pre-AAVS1 and AAVS1 (Q4 2016).
  - The new design may require a slight increase in the station diameter (up to ~40-45 m to maintain the antenna density and accessibility).

Conclusions

- AAVS1 antennas + LNAs are ready
- Optimization of SKALA2 -> SKALA3 under control and on its way

Thank you