Radio frequency interference mitigation for astronomy with phased array feeds

Supervisors: Prof. Tara Murphy - University of Sydney, Sydney Institute for Astronomy
Dr. Aaron Chippendale – CSIRO, Space and Astronomy

- **Context (instrument, PAFs, scope)**
- **Unwanted Signal**
  - **Spatial Signatures**
- **Beamforming and Weights**
- **Spatial Nulling using Projection Techniques**
  - **Forward Predictions**

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Credit: CSIRO

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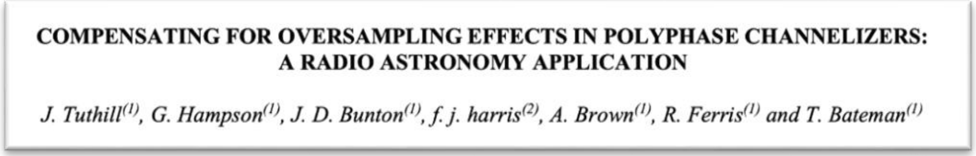
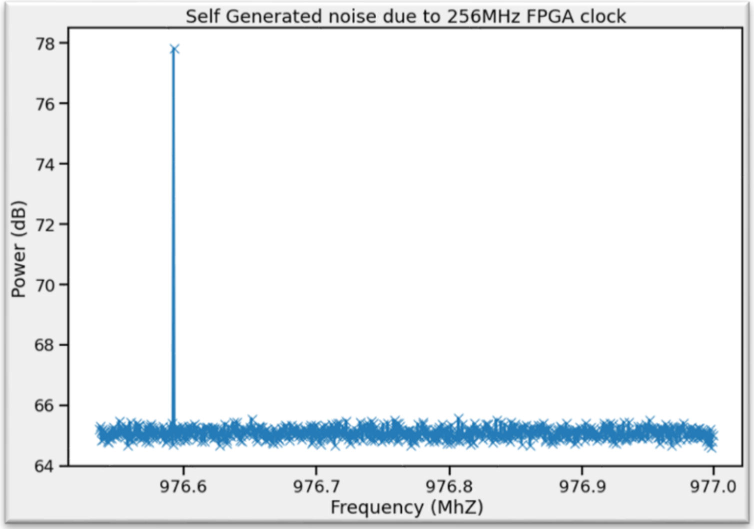
- **Spatial nulling using phased array feeds has been shown experimentally to successfully mitigate RFI.**
- **More work is required to understand the effects of these algorithms on astronomical figures of merit.**
  - **Promote adoption by astronomers**

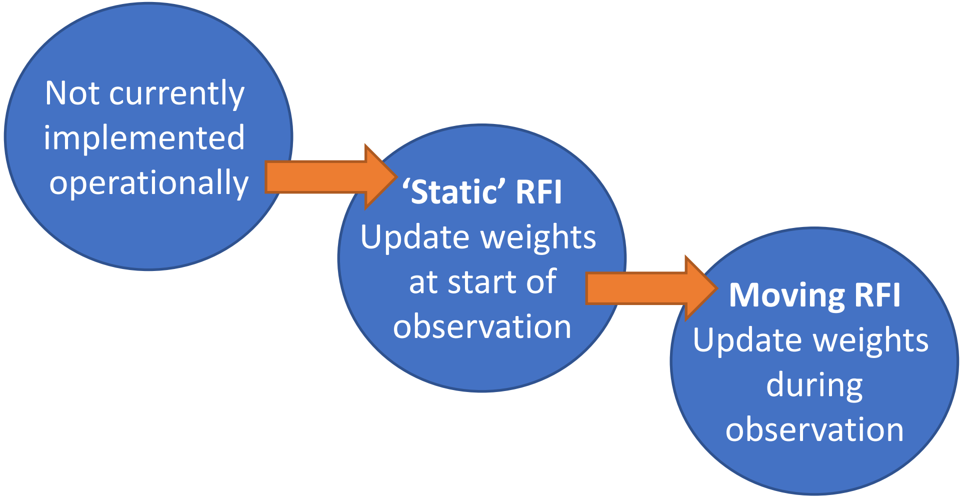
Credit: CSIRO

- **Self-generated tone from ASKAP receiver electronics.**
- **Signal is <u>not moving</u> & can be mitigated at the beginning of an observation**


COMPENSATING FOR OVERSAMPLING EFFECTS IN POLYPHASE CHANNELIZERS: A RADIO ASTRONOMY APPLICATION

J. Tuthill[(1)], G. Hampson[(1)], J. D. Bunton[(1)], f. j. harris[(2)], A. Brown[(1)], R. Ferris[(1)] and T. Bateman[(1)]





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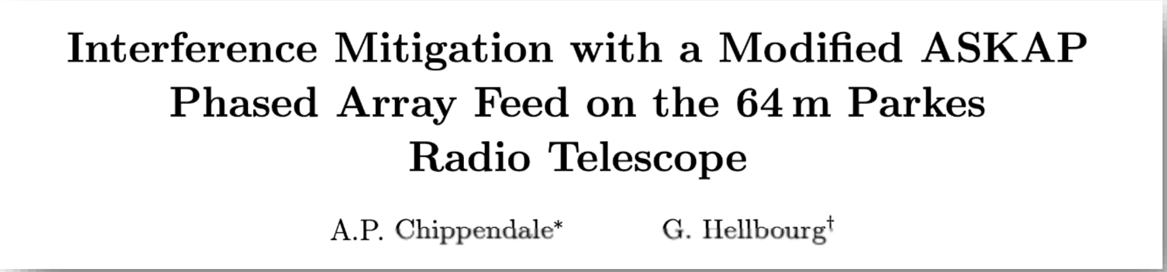
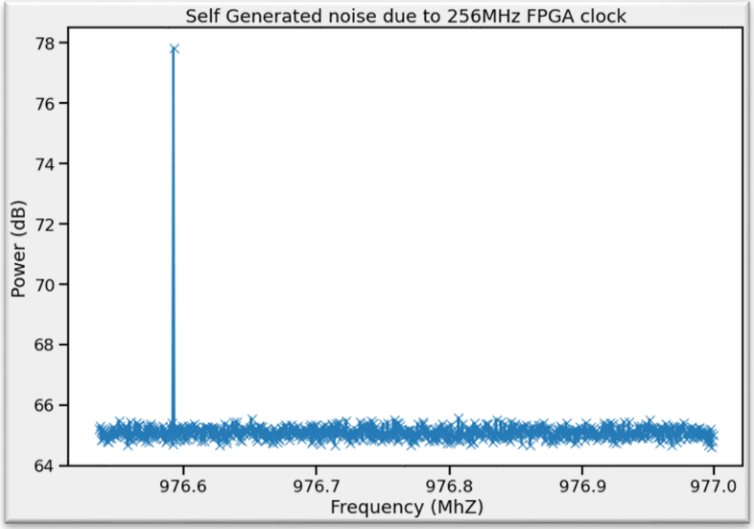


Interference Mitigation with a Modified ASKAP Phased Array Feed on the 64 m Parkes Radio Telescope

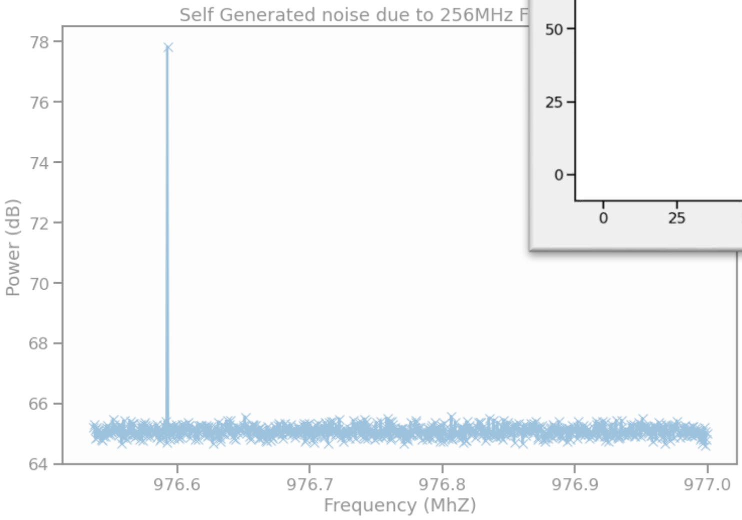
A.P. Chippendale* G. Hellbourg†

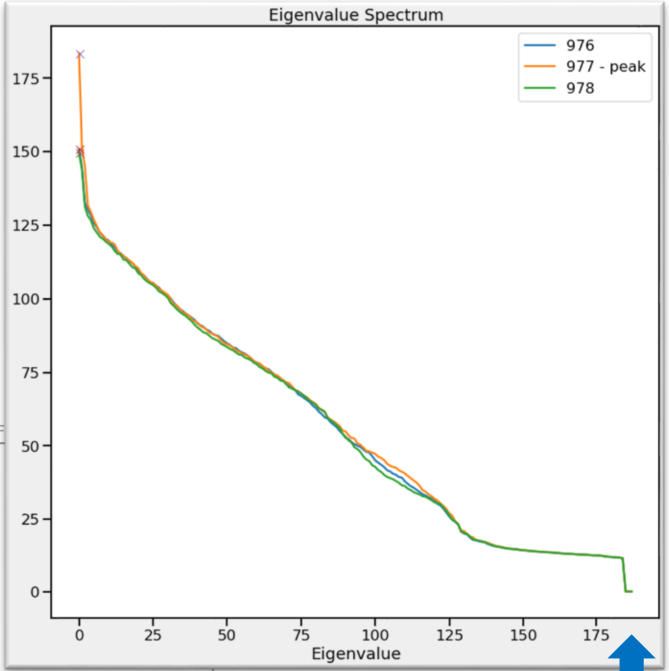
- signal cleanly mitigated to the noise floor with no reduction in system sensitivity.

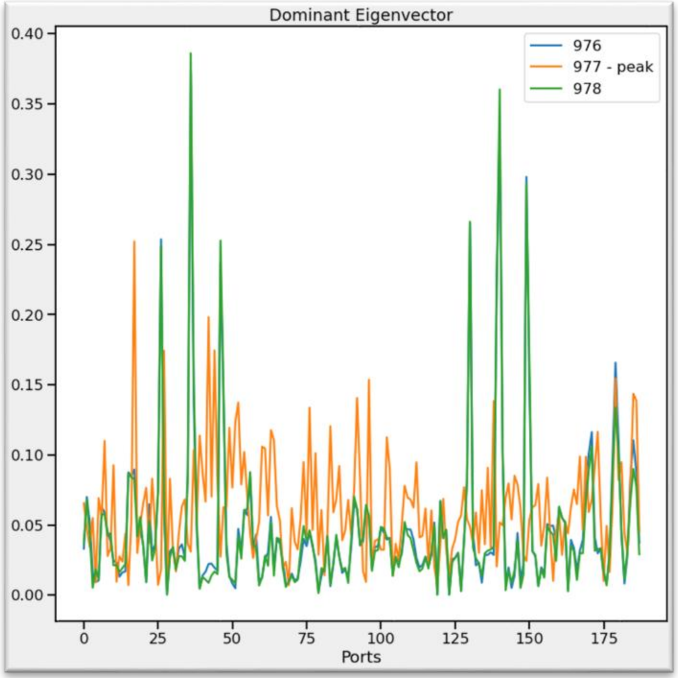


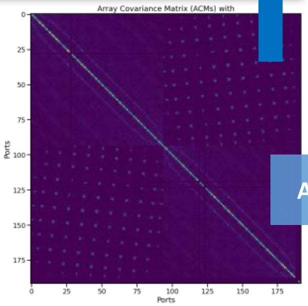
Astronomers are not only interested in suppression. In order to adopt the RFI mitigation techniques, they need to <u>understand the effects of the spatial nulling using projection algorithms on the beam-shape, gain, polarization</u> etc.

- **Self-generated tone from ASKAP receiver electronics.**
- **Signal is <u>not moving</u> & can be mitigated at the beginning of an observation**





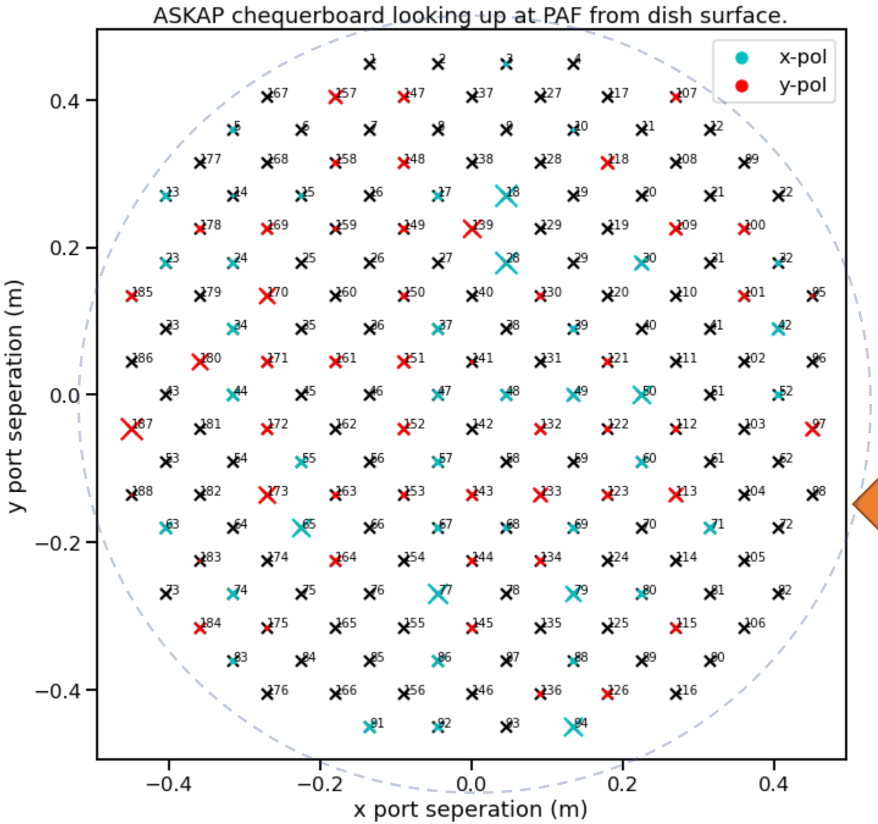




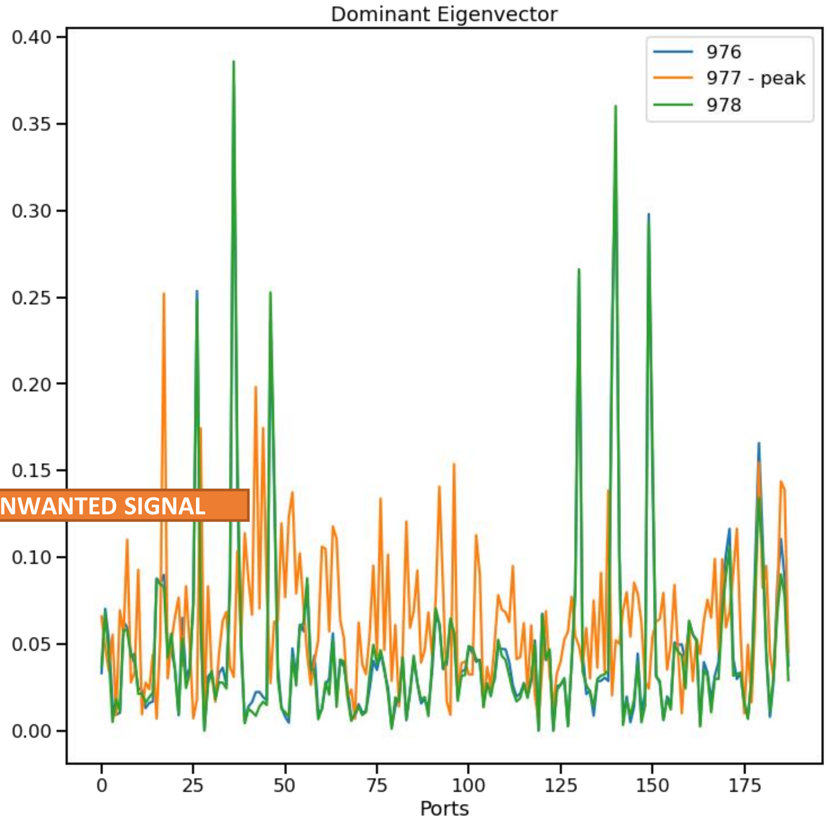
ACM

1 MHz channels

dominant eigenvector (orange) is used as the **spatial signature** of the unwanted signal in the mitigation algorithm.

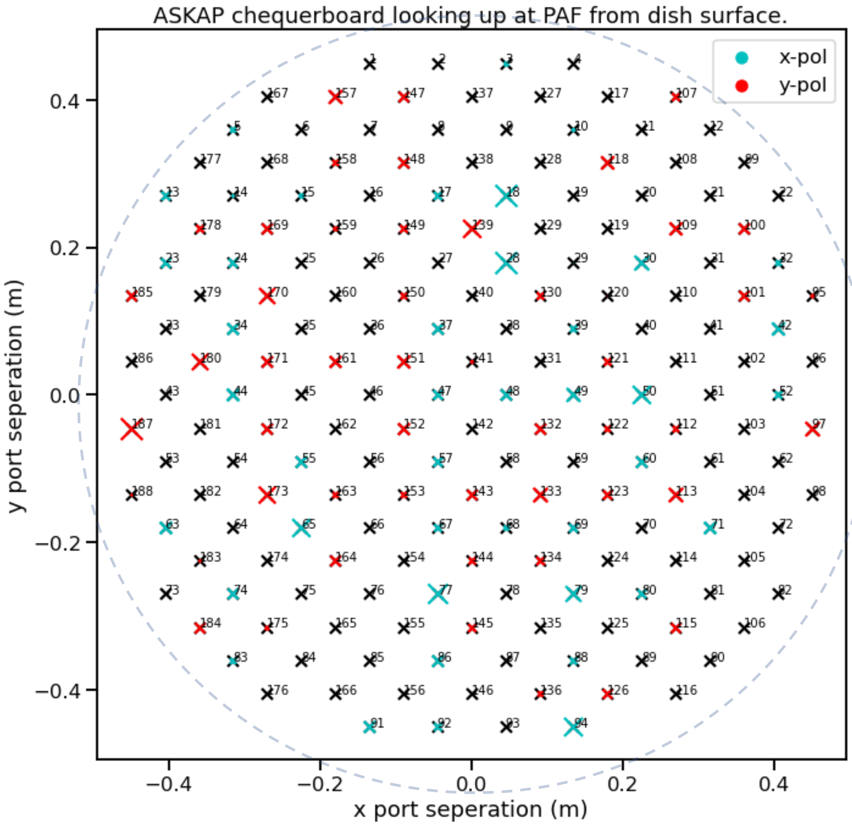


UNWANTED SIGNAL

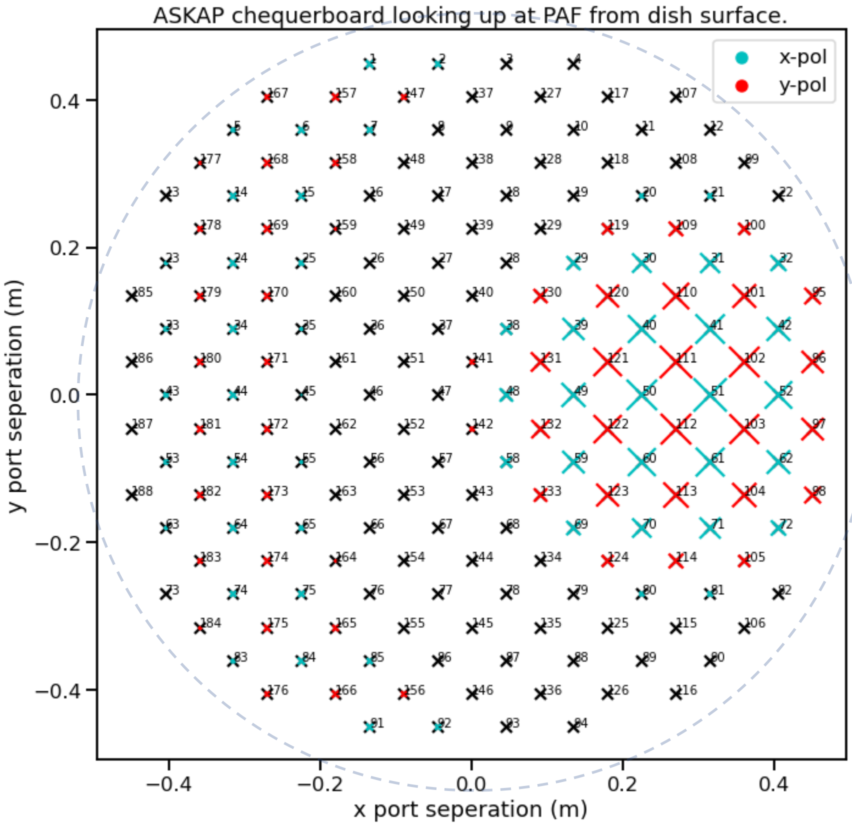


Spatial Signature to suppress

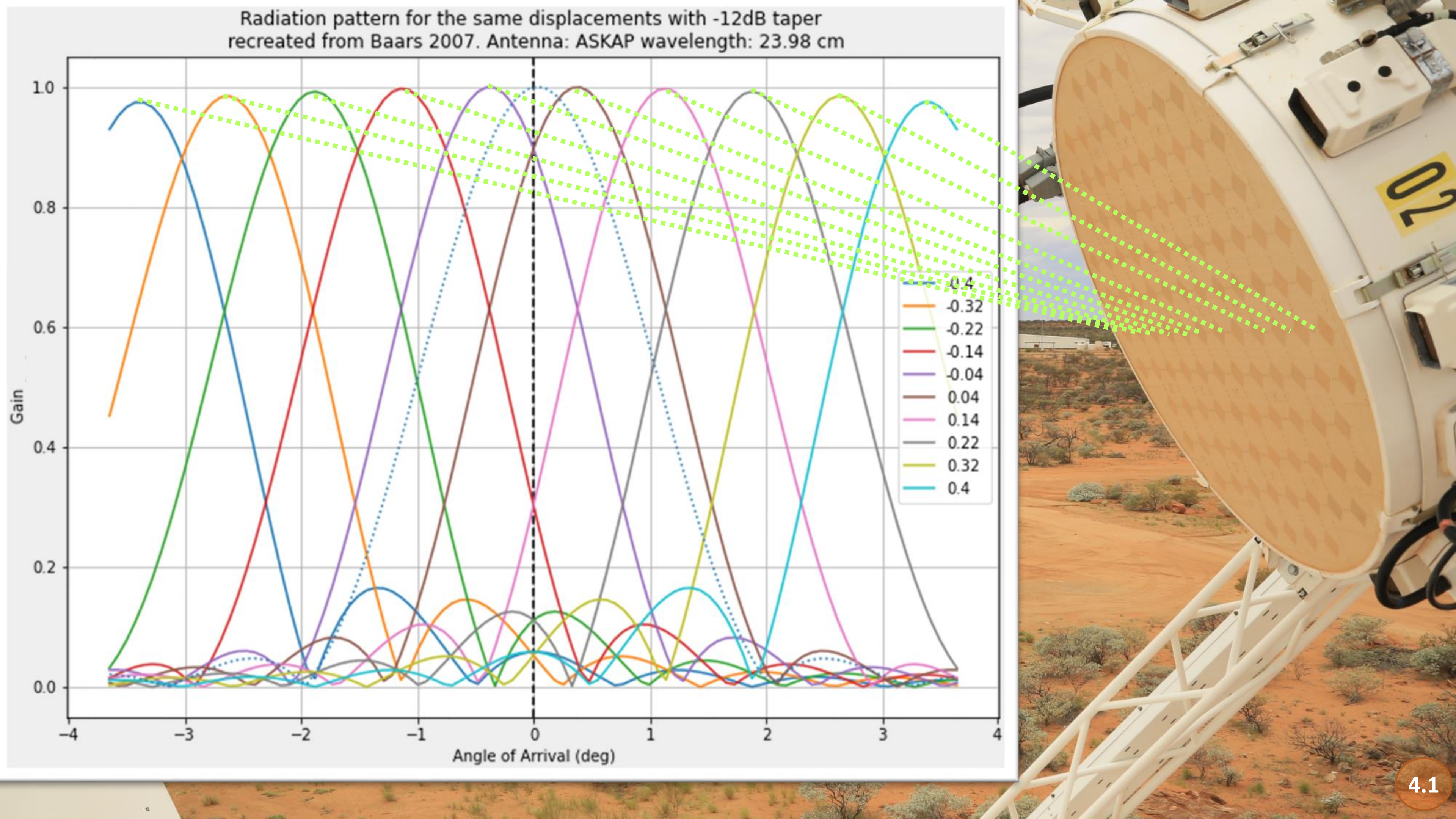
3.1

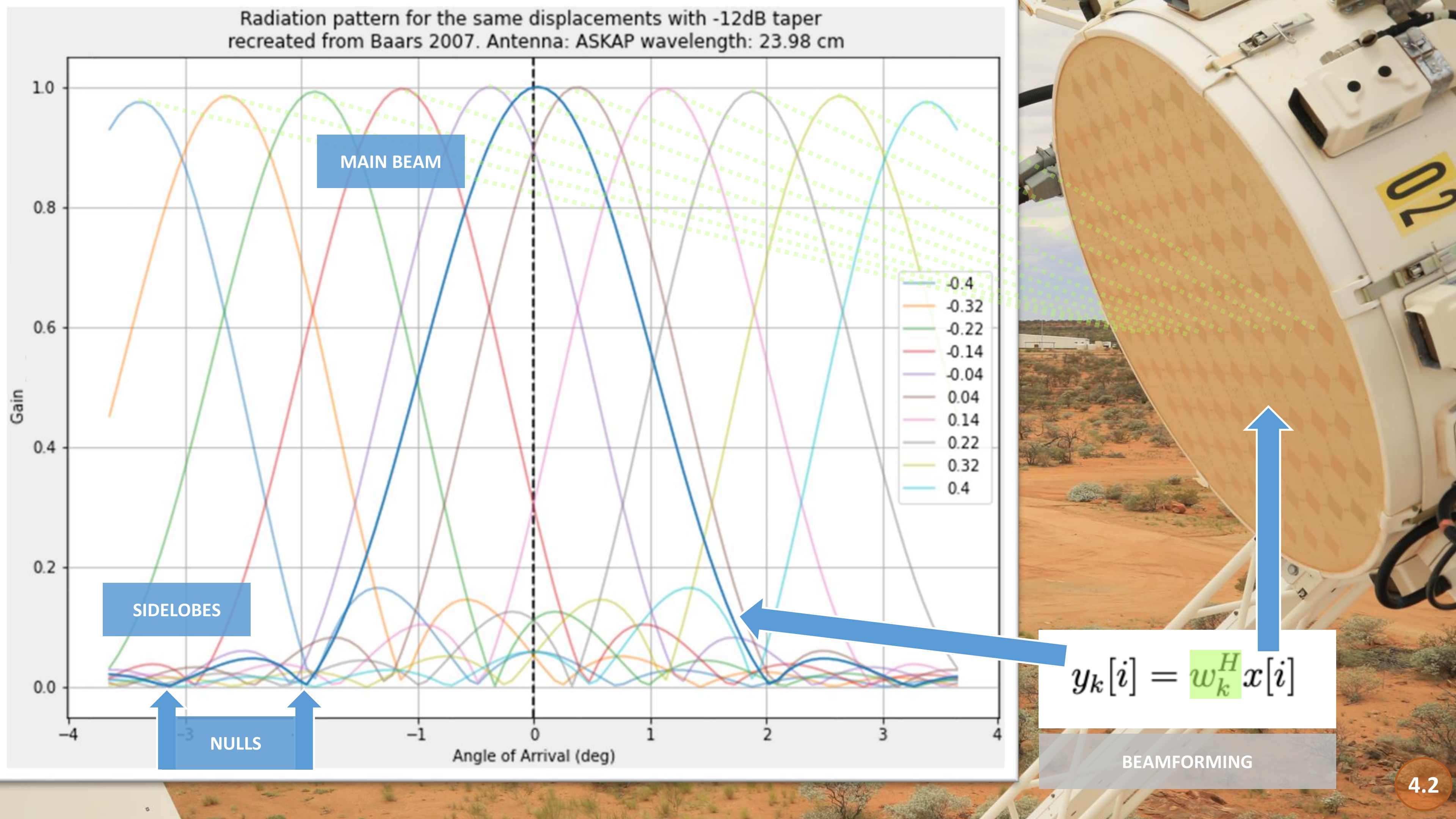


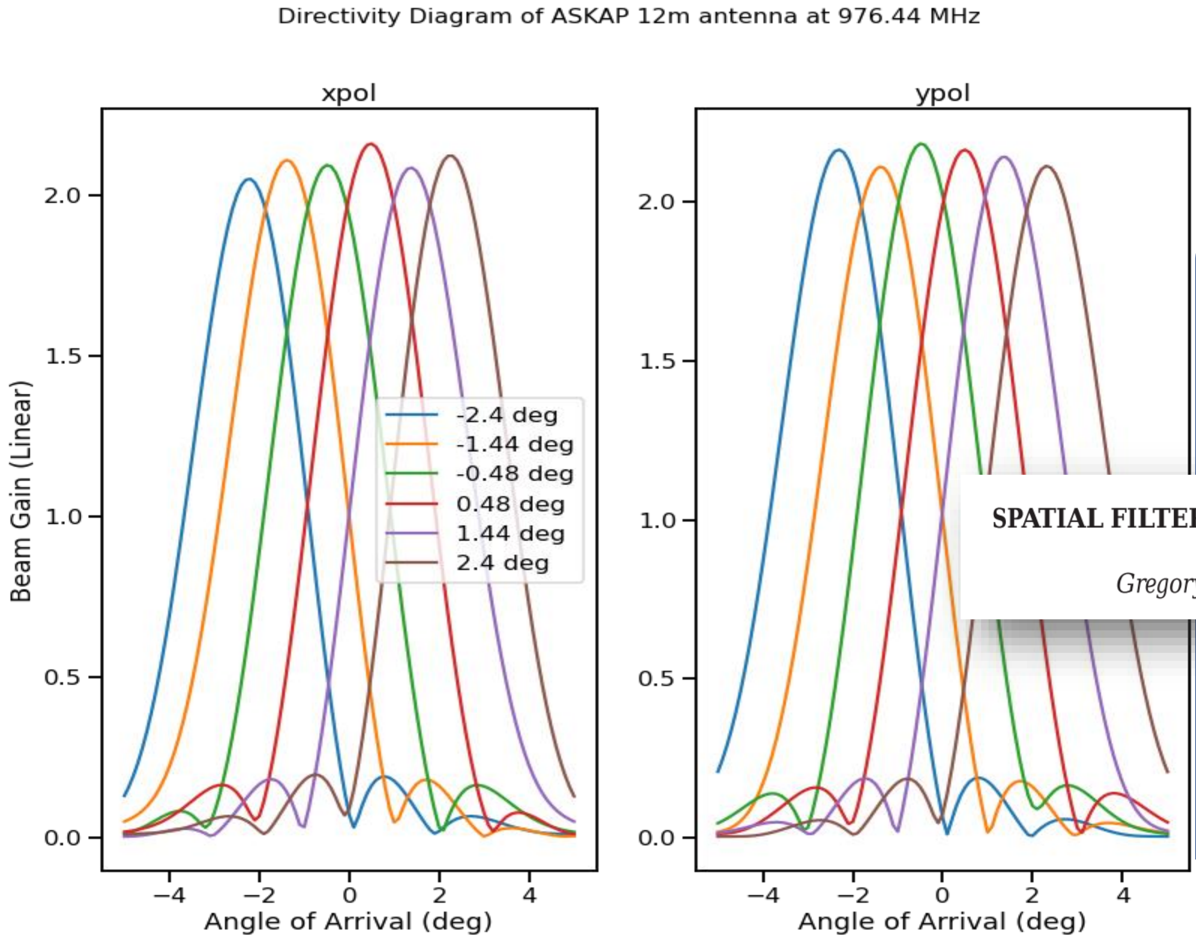
Spatial Signature to suppress



Spatial Signature to preserve


Radiation pattern for the same displacements with -12dB taper
recreated from Baars 2007. Antenna: ASKAP wavelength: 23.98 cm
Gain
0.0
0.2
0.4
0.6
0.8
1.0
−4
−3
−2
−1
0
1
2
3
4
Angle of Arrival (deg)
-0.4
-0.32
-0.22
-0.14
-0.04
0.04
0.14
0.22
0.32
0.4
02


Radiation pattern for the same displacements with -12dB taper
recreated from Baars 2007. Antenna: ASKAP wavelength: 23.98 cm
MAIN BEAM
SIDELOBES
NULLS
Gain
Angle of Arrival (deg)
1.0
0.8
0.6
0.4
0.2
0.0
−4
−3
−1
0
1
2
3
4
-0.4
-0.32
-0.22
-0.14
-0.04
0.04
0.14
0.22
0.32
0.4
$y_k[i] = w_k^H x[i]$
BEAMFORMING
4.2



Beamforming is the **weighted sum** of ASKAPs 188 element chequerboard PAF ports.

$$y_k[i] = w_k^H x[i]$$

Spatial filtering achieved by **altering weights** using projections algorithms

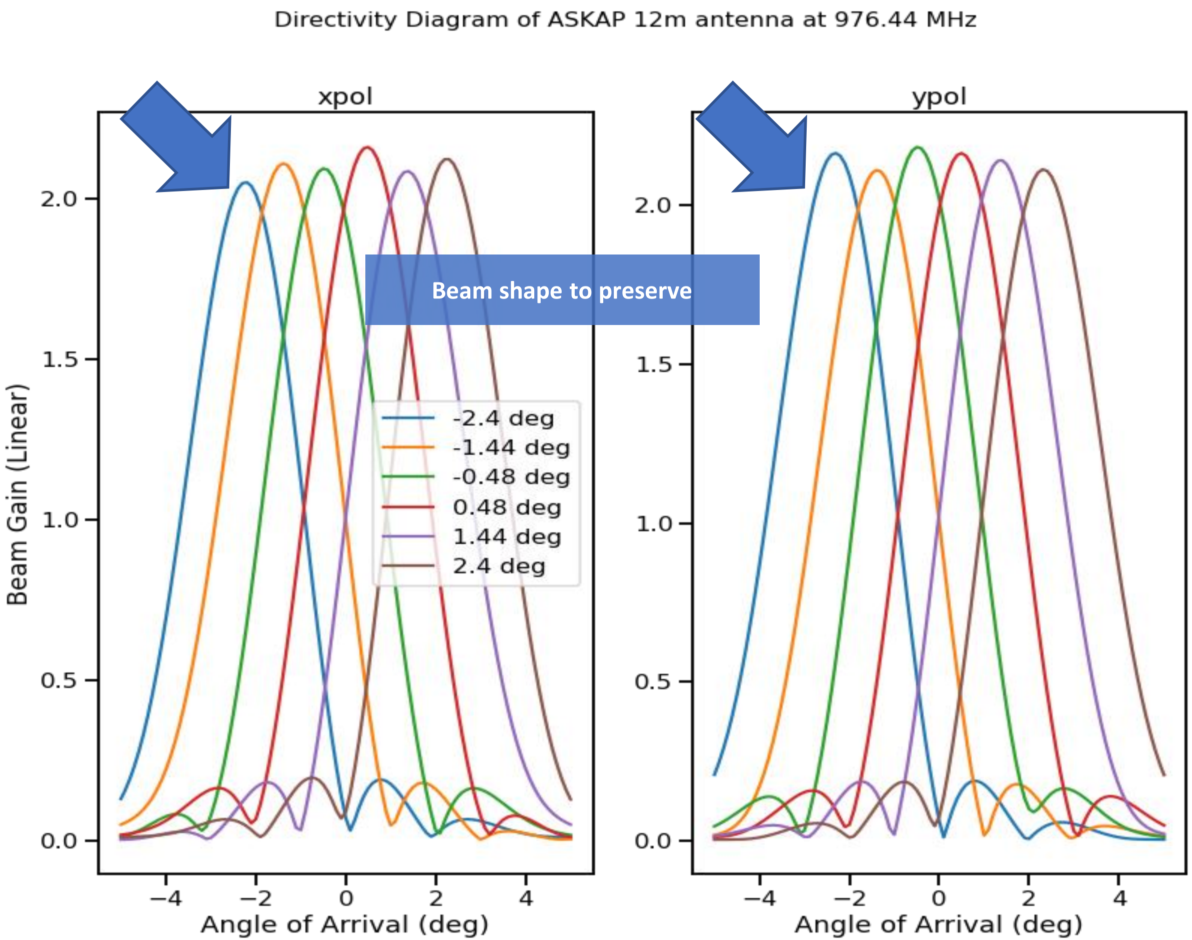
SPATIAL FILTERING EXPERIMENT WITH THE ASKAP BETA ARRAY

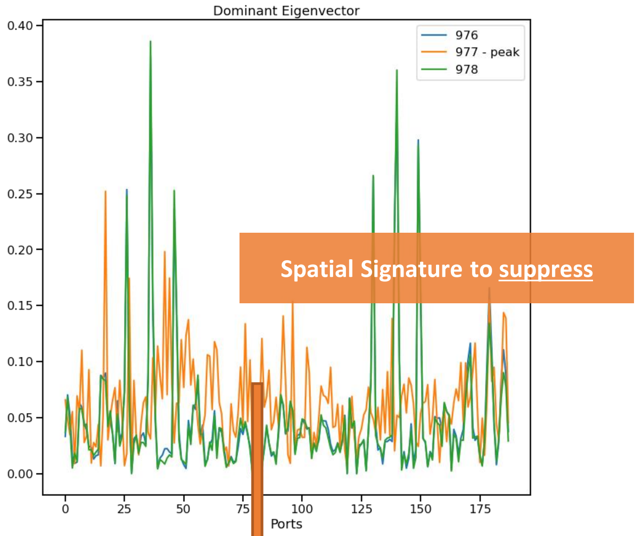
Gregory Hellbourg[1,2], Keith Bannister[2], Aidan Hotan[2]

$$P_{ortho} = a_r(a_r^H a_r)^{-1} a_r^H$$

$$P_{obliq} = a_s(a_s^H P_{ortho} a_s)^{-1} a_s^H P_{ortho}$$

$$w_{Proj} = P^H a_s$$

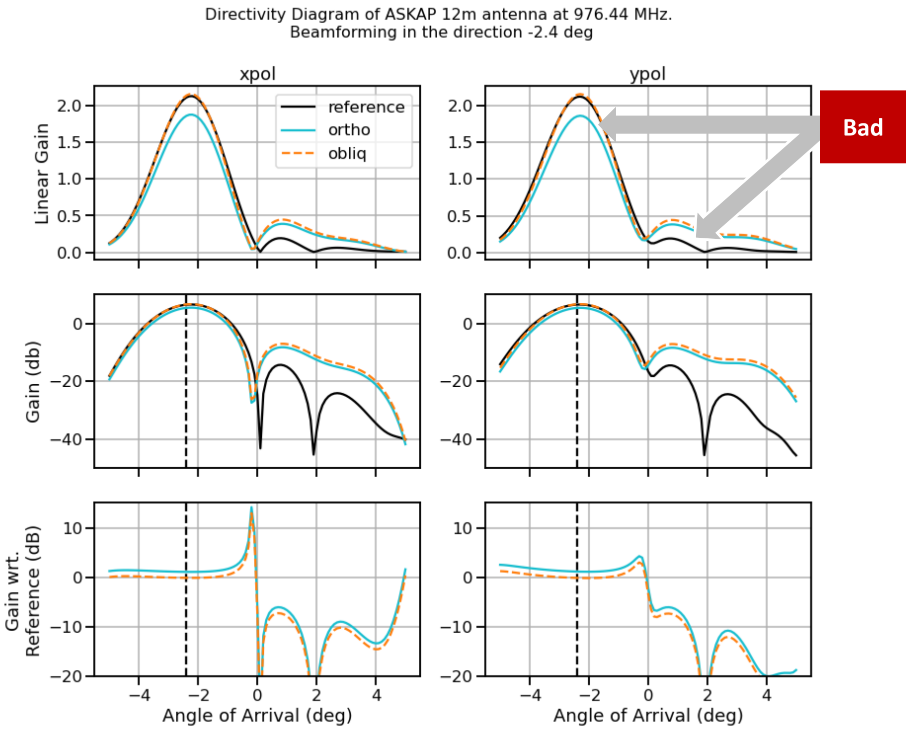




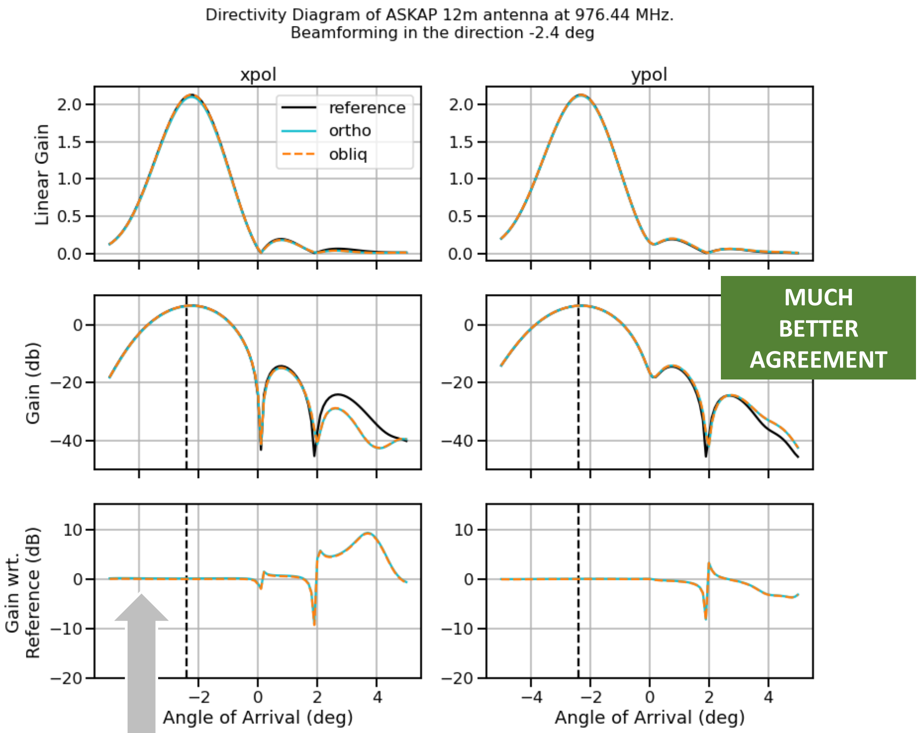
$$P_{ortho} = a_r(a_r^H a_r)^{-1} a_r^H$$

$$P_{obliq} = a_s(a_s^H P_{ortho} a_s)^{-1} a_s^H P_{ortho}$$

PROJECTION TECHNIQUES



Coherent Phase on all ports



Different Phase on all ports

Variations to the beampatterns are reduced when the phase of the self-generated signal is random, **particularly in the sidelobes.**

Forward Predictions

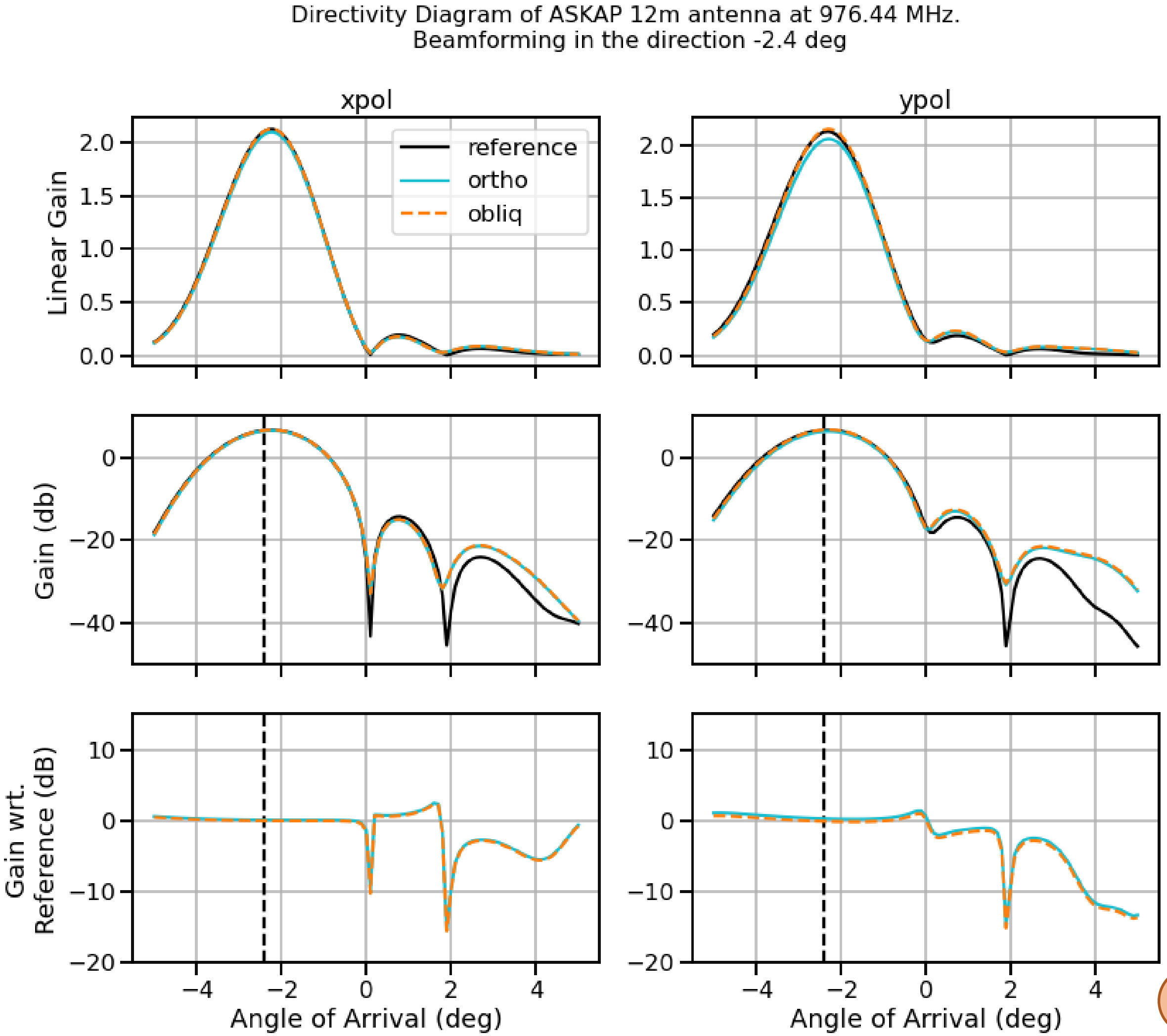
- Based on the model we expect >125 dB **suppression**
  - Less if gains/temperatures of electronics change

- **system-temperature-over-efficiency** (sensitivity)

T_{sys}/η
  - 3% increase on average
  - up to 11% increase

Given this kind of information astronomers are in a better position to understand what the mitigation algorithm is doing.

Astronomers can make informed decisions in choosing to use this RFI mitigation technique based on their science goals.



Questions?

Next Steps:

- Implement and evaluate static use case on ASKAP
- Model, implement and Evaluate the dynamic case
  - adjusting beam weights continuously throughout the observation
  - mitigate more pervasive RFI from moving sources, e.g. signals from satellites and aircraft.

Acknowledgements and Thanks

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