

Spatial RFI mitigation for ASKAP

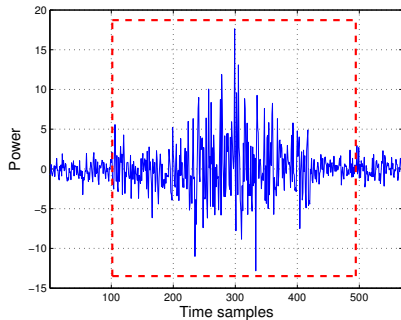
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CSIRO Astronomy and Space Science

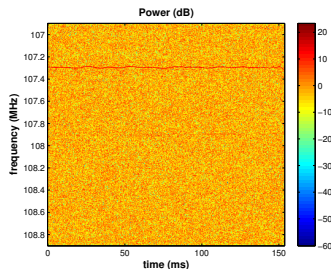
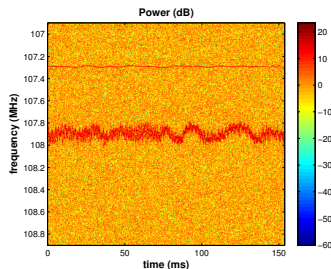
Active RFI mitigation

- Time/Frequency domain
 - Flagging / blanking
 - Digital (adaptive) filtering
 - Estimation and subtraction
 - ...
- Spatial domain
 - Adaptive beamforming
 - Subspace projection
 - ...



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Spatial RFI mitigation - Concept



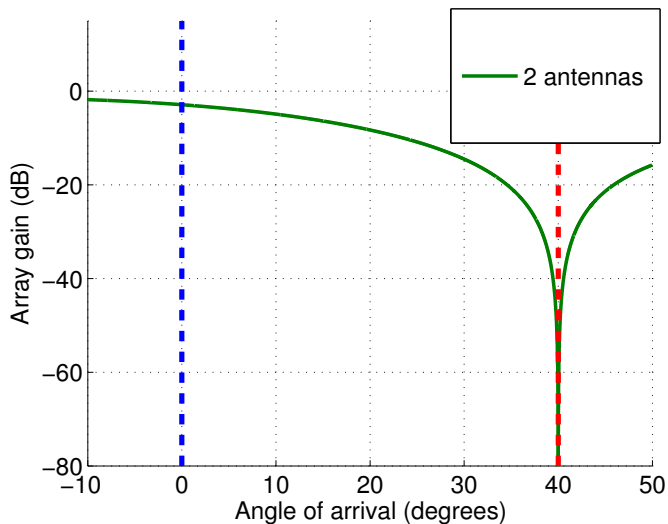
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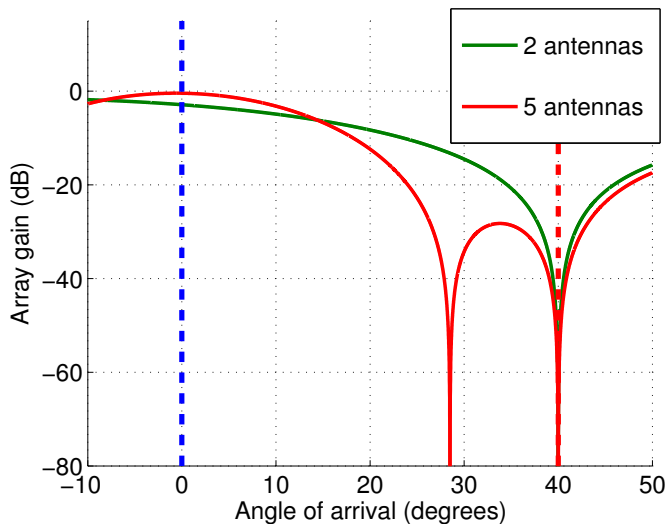
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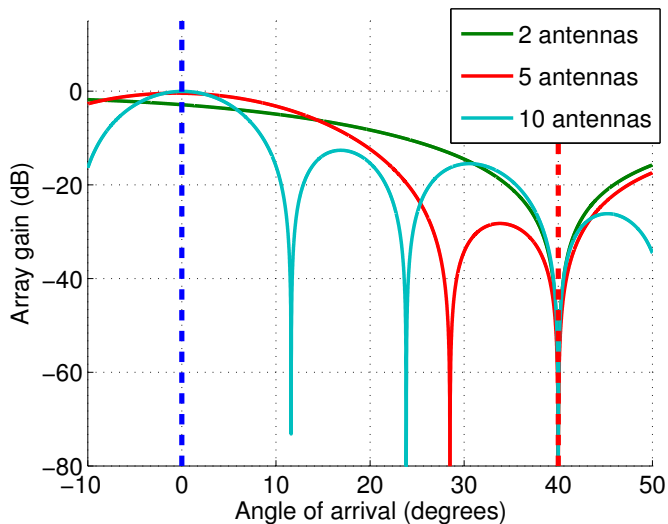
Multi-elements - subspace projection



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Multi-elements - subspace projection



Spatial filtering with interferometers

Max. baseline $\approx \lambda \Rightarrow$ “phased” array

Max. baseline $\gg \lambda \Rightarrow$ “timed” array

Interferometric data model

$$\begin{cases} x_1(t) = a_{r_1} r(t) & + a_{s_1} s(t) & + n_1(t) \\ x_2(t) = a_{r_2} r(t - \tau_{r_2}) & + a_{s_2} s(t - \tau_{s_2}) & + n_2(t) \\ \vdots & & \end{cases}$$

Visibility / covariance

$$\begin{aligned} V_{n,m} = \mathbb{E} \{ x_n(t) x_m^*(t - \tilde{\tau}) \} &= [a_{r_n} a_{r_m}^*] \mathbb{E} \{ r(t) r(t - \tilde{\tau}) \} + \\ & [a_{s_n} a_{s_m}^*] \sigma_s^2 + \\ & \mathbb{E} \{ n_n(t) n_m^*(t - \tilde{\tau}) \} \end{aligned}$$

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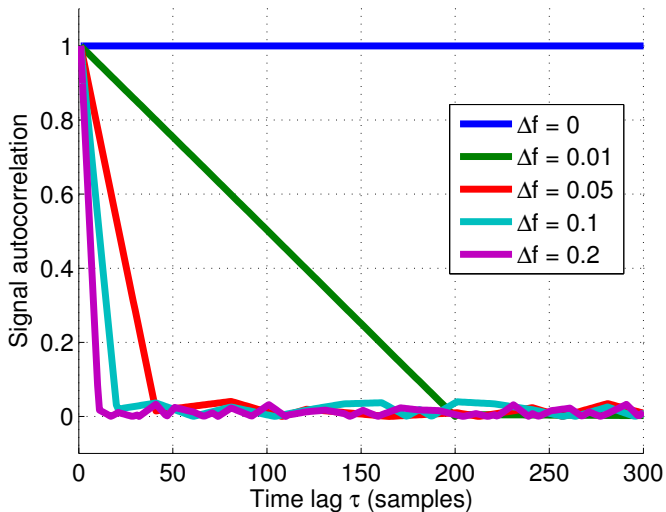
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Spatial filtering with interferometers



Spatial filtering with interferometers

Narrow band processing limitations:

- Large baselines constraint narrow band processing
- Spatial filtering performance limited at central correlator

Options for spatial filtering:

- Secondary receivers / phased array feeds
- Reference antenna / phased array
- Sub-array processing (shorter baselines)
- Wide band beamformers

Adaptive beamformer

Adaptive filter:

$$\mathbf{w}_{\text{adapt}} = \underset{\mathbf{w}}{\text{argmax}} \quad \text{astro sensitivity}$$

subject to $\text{gain RFI} = 0$

Requires knowledge of:

- astro spatial information (\approx direction of interest)
- RFI spatial information (\approx ?? - a priori knowledge? primary / side lobe?...)

Adaptive beamformer

Adaptive filter:

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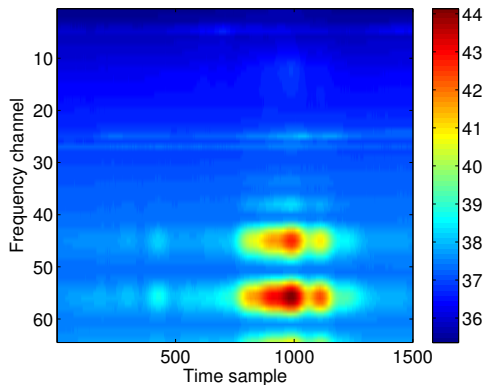
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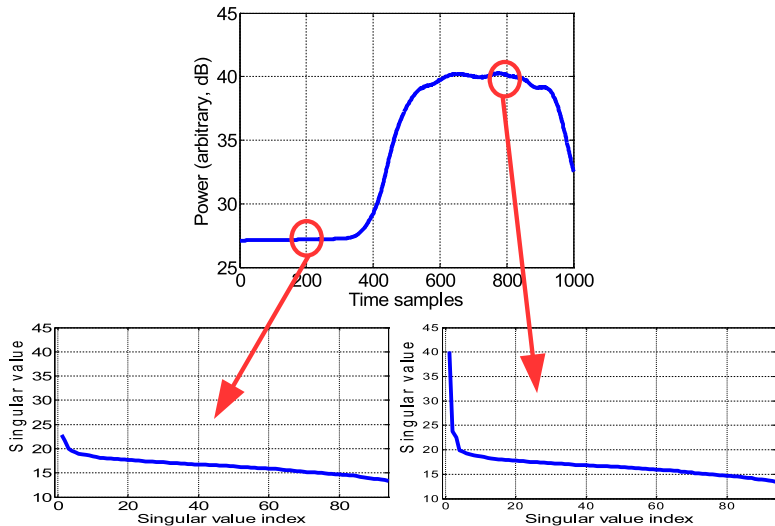
- **astro spatial information** (\approx direction of interest)
- **RFI spatial information** (\approx ?? - a priori knowledge? primary / side lobe?...)

RFI spatial contribution estimation

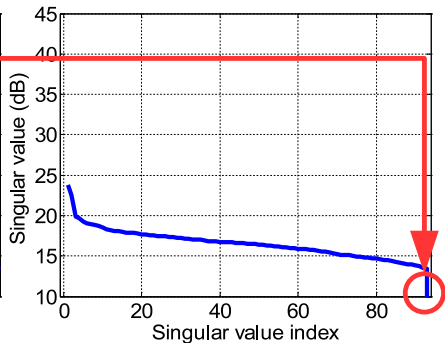
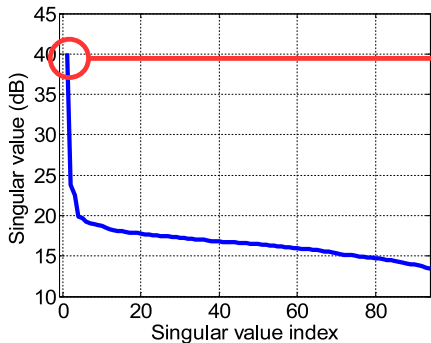
ASKAP - Galileo satellite “drift scan”



RFI spatial contribution estimation

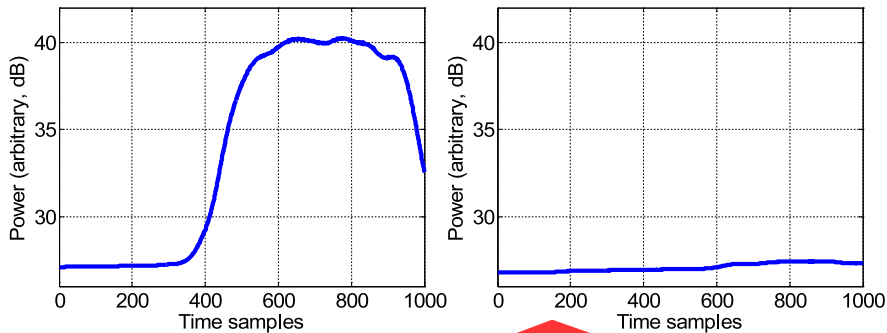


RFI subspace projection



Projector

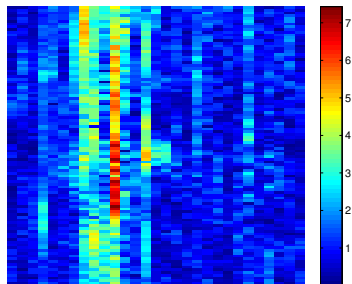
RFI subspace projection



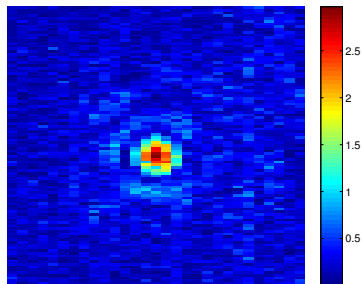
Projection

Example : Holographic measurement cleaning

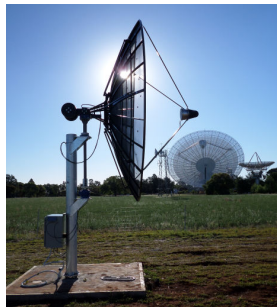
Corrupted BETA beam:



BETA beam after projection:

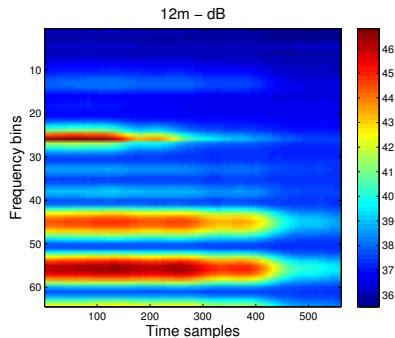


Reference antenna

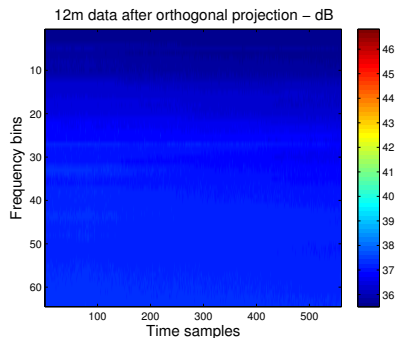


Reference antenna with single target

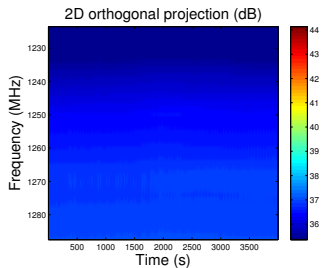
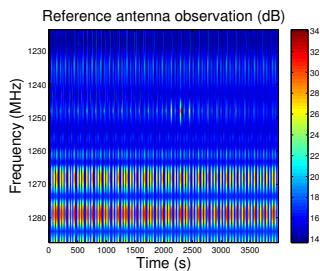
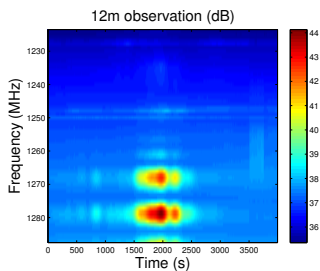
Corrupted data:



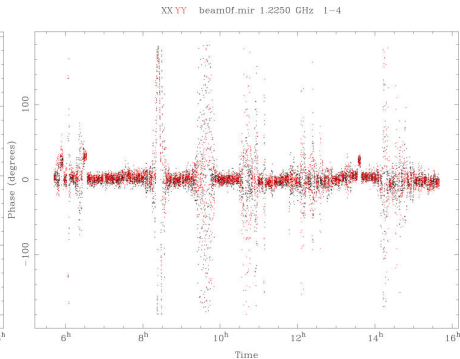
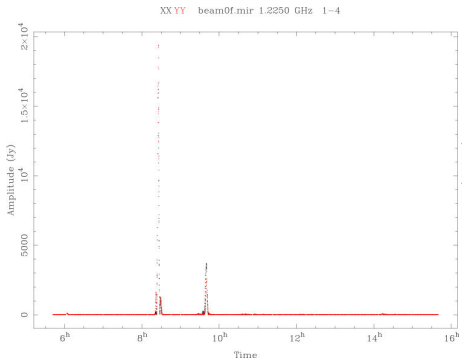
Result after projection



Reference antenna with multiple targets

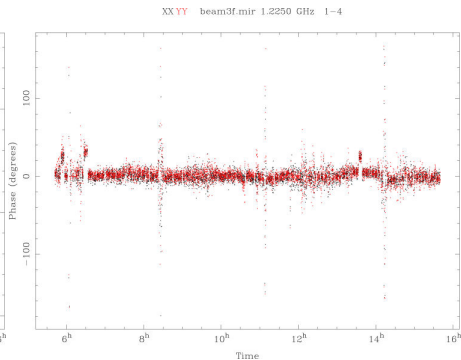
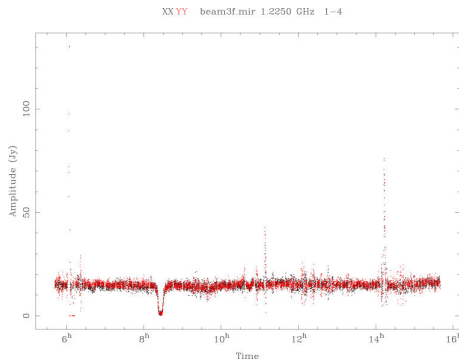


PKS 1934-63 - 10h @ 1,225 MHz - 5 BETA ants - before processing



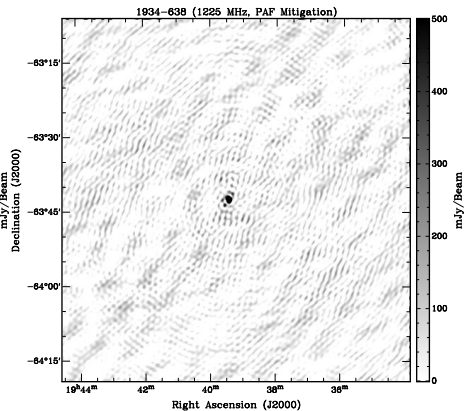
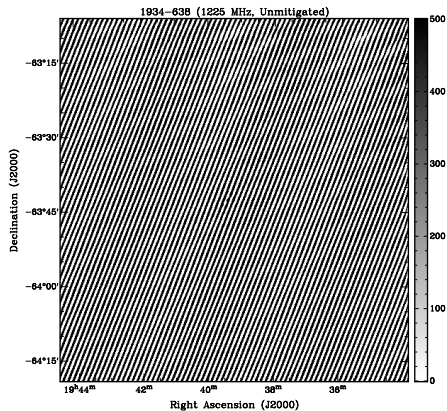
AK01 - AK06

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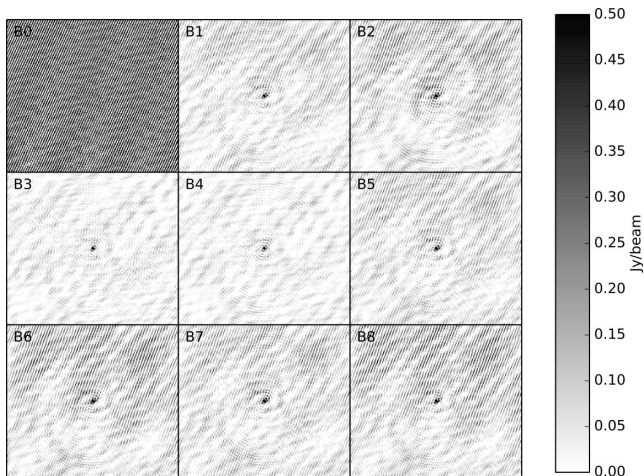


AK01 - AK06

Imaging results



Imaging results : Multi-algorithms



Conclusion

- RFI : increasingly threatening radio astronomy
- Current approaches (flagging/excision) are limiting the instrument performance
- Spatial filtering recovers uncorrupted T-F data
- Various “low-cost” implementation options
- “Blind” / informed options available
- Real time spatial RFI cancellation recently demonstrated
- Further analysis on synthesized beam to be conducted

RFI 2016

Coexisting with Radio Frequency Interference

October 17-20, 2016



Hosted by the
National Radio Astronomy Observatory (NRAO)
at the New Mexico Tech Macey Center
in Socorro, New Mexico (USA)

Important dates:

Abstract submission: ..	1 August 2016
Author registration: ...	15 September 2016
Conference:	17-20 October 2016
Proceeding submission:	6 November 2016