Interference Mitigation Using a Multiple Feed Array for Radio Astronomy

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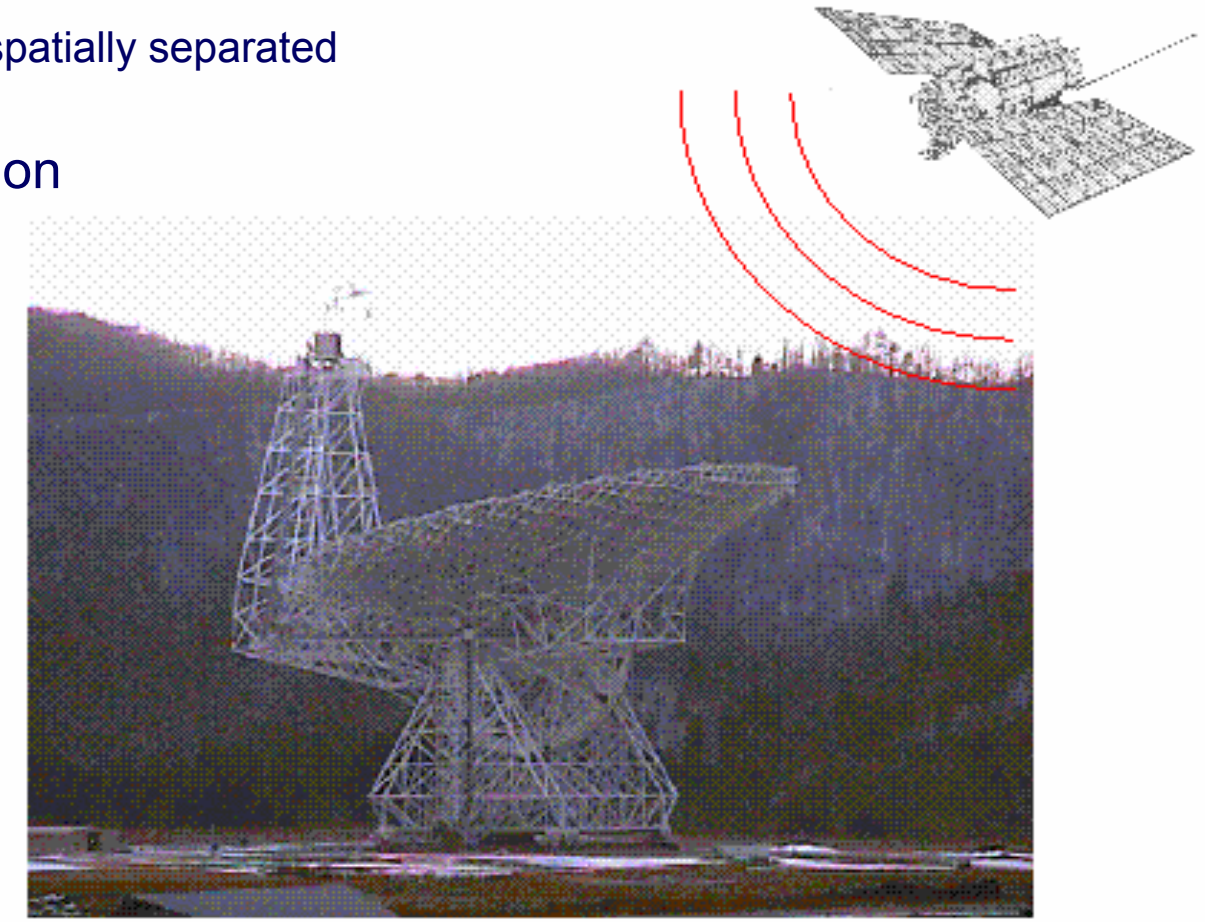
RFI Mitigation

Techniques:

- Spatial filtering
  - Requires multiple spatially separated looks at interferer
- Adaptive cancellation
- Time blanking



Array Feed - Design Goals

- *High Sensitivity*
  - Sensitivity = $\frac{\text{Gain}}{\text{System Temperature}} \sim \text{SNR}$
  - $T_{sys} = T_{receiver} + T_{spillover} + T_{Interference} + T_{atmosphere} + T_{cmb}$
- *Beam steering*
  - Beam shape control
  - Gain stability
- *RFI Mitigation*

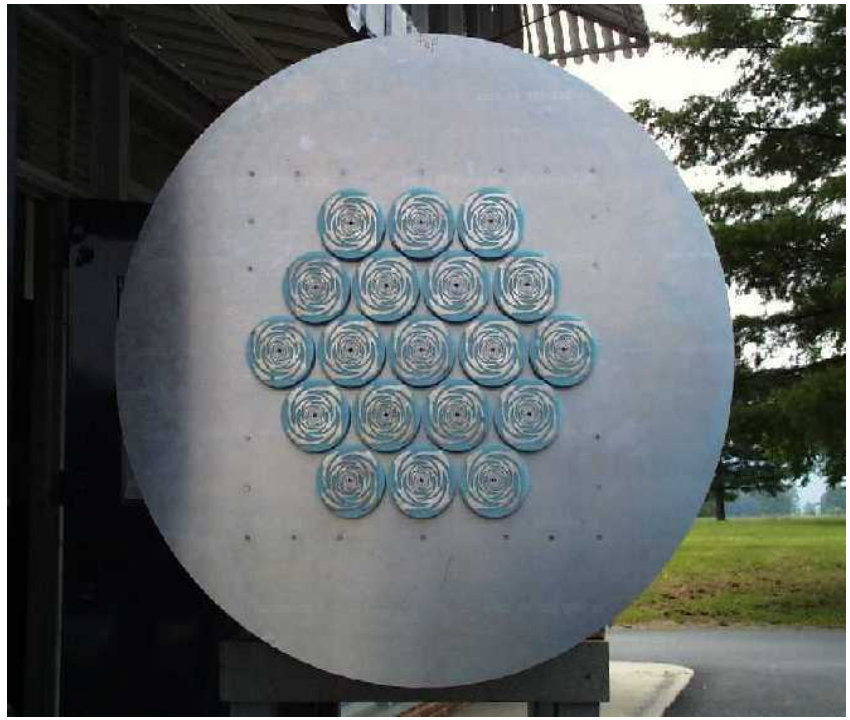
Previous Work: Array Feeds

- Most implementations: 1 feed = 1 beam

e.g: Parkes HIPASS Array – Multibeam feed.

19-element Array at NRAO

- Electrically small elements
- Hexagonal array
- Beamforming



Approach

- 25 meter paraboloid
- GRASP8 (TICRA) PTD reflector analysis software
- Array weights – three methods:
  - Conjugate field match (CFM)
  - Brute force sensitivity optimization
  - Max SNR/LCMV (beamforming + RFI nulling)
- Compare to single waveguide feed

Assumptions

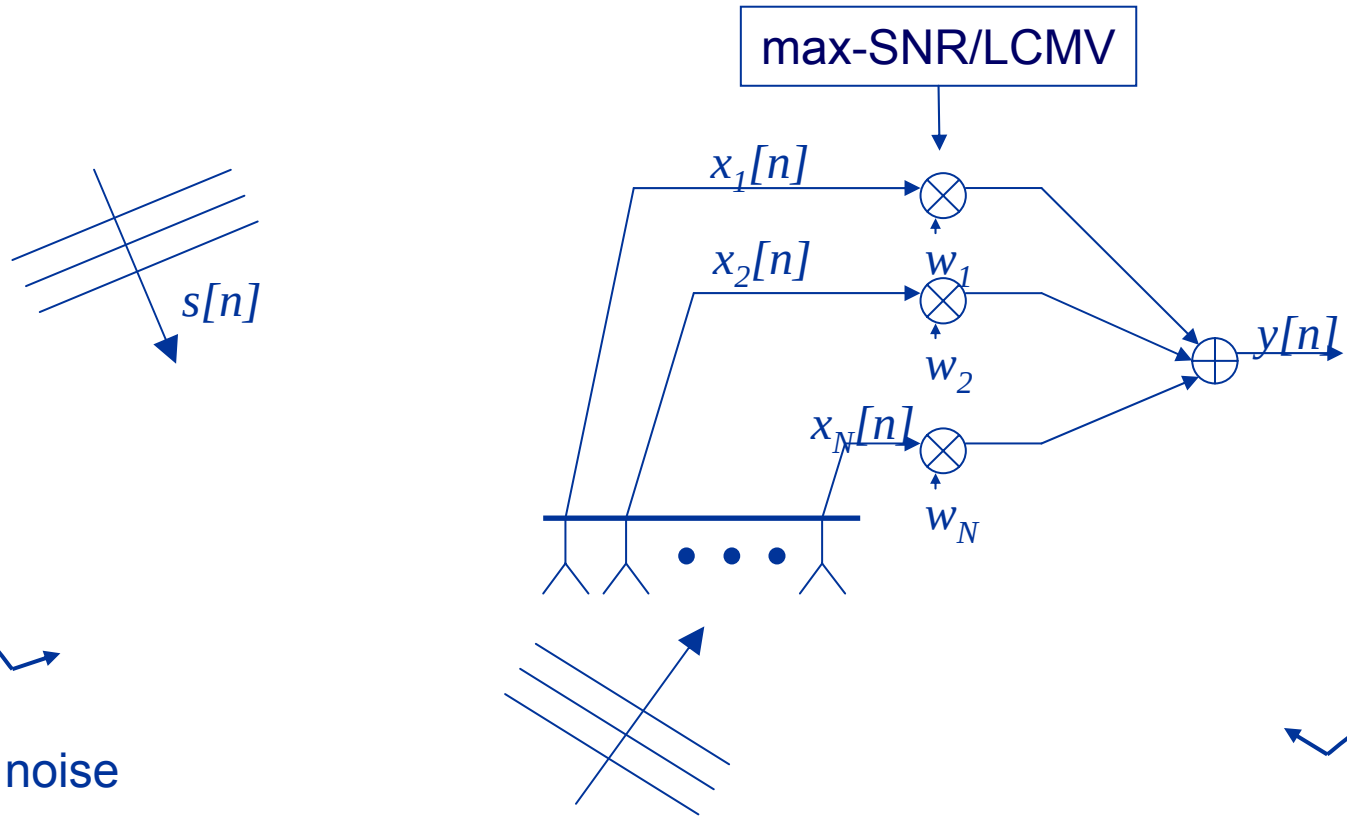
Array:

- Operating frequency: 1612 MHz
- 7 and 19-element hexagonal arrays with 0.6λ spacing
- Hertzian dipoles
- No mutual coupling between array elements
- Hemispherical element patterns

Noise model:

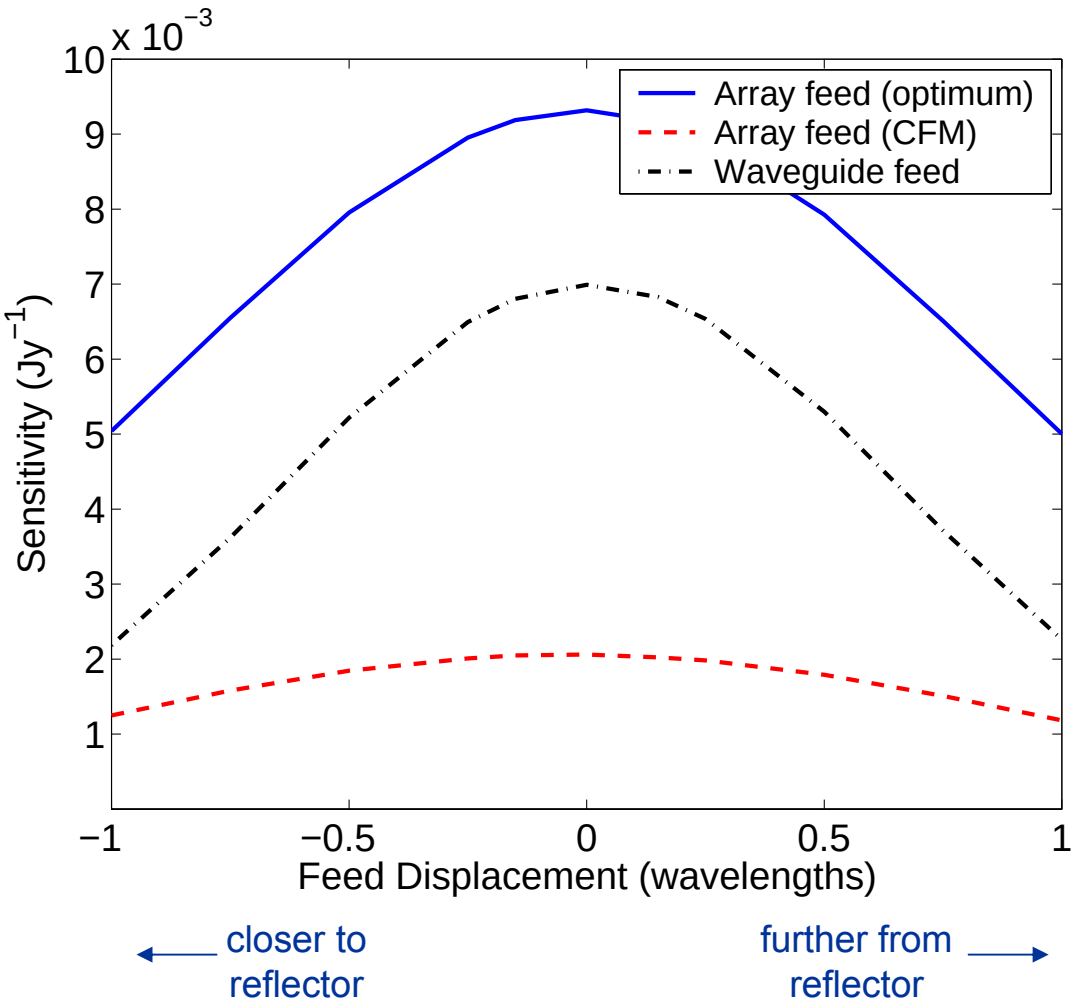
- Individual LNA noise temperature: 15 K
- Spillover noise: 300K warm ground below reflector
- Atmospheric and cosmic background noise is neglected

Interference Mitigation

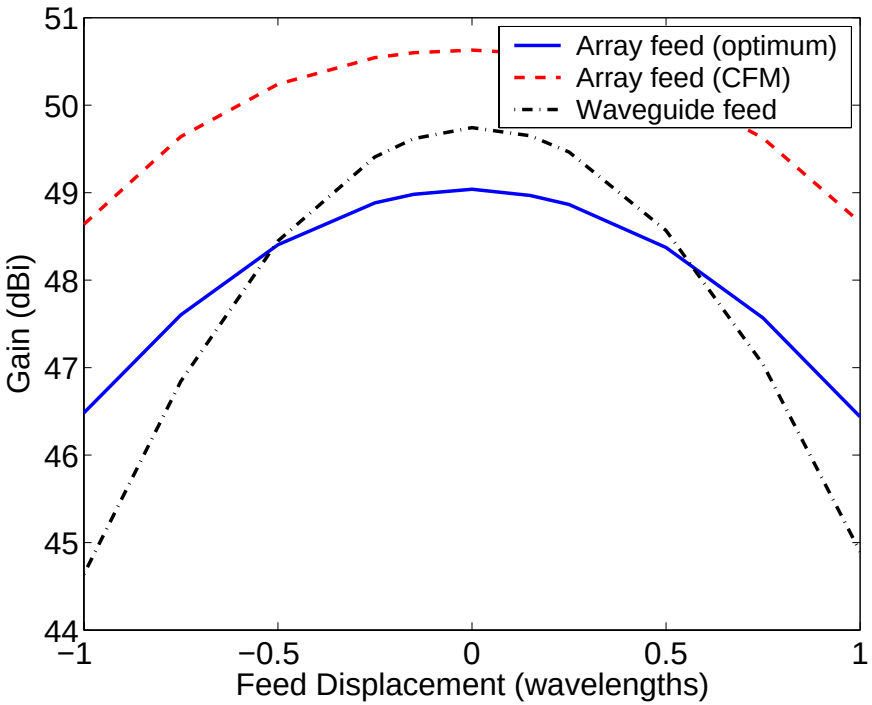


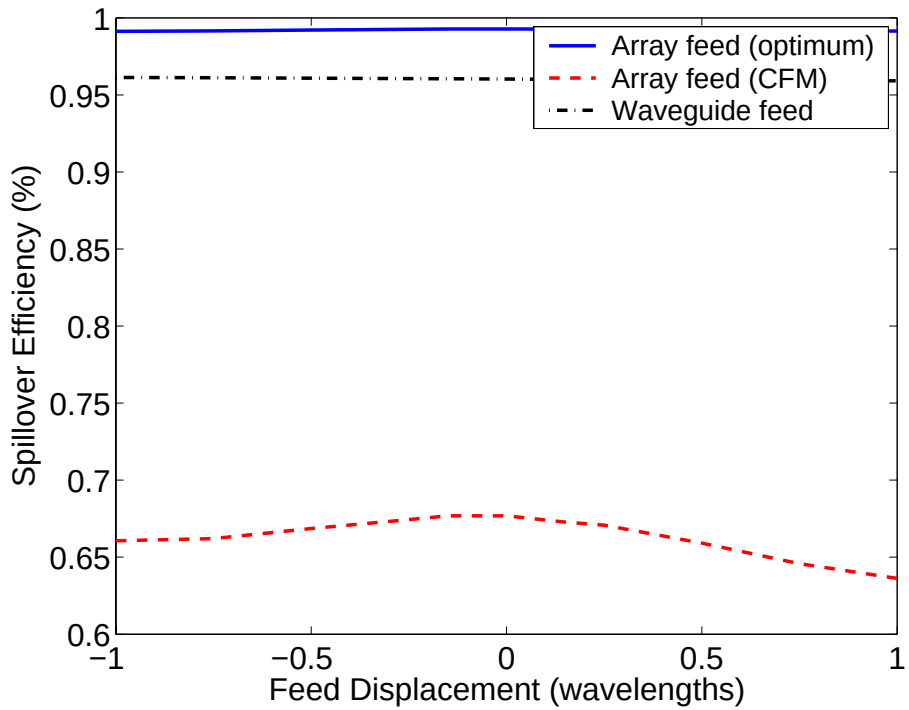
Sensitivity

- 25 meter reflector
- Boresight beam

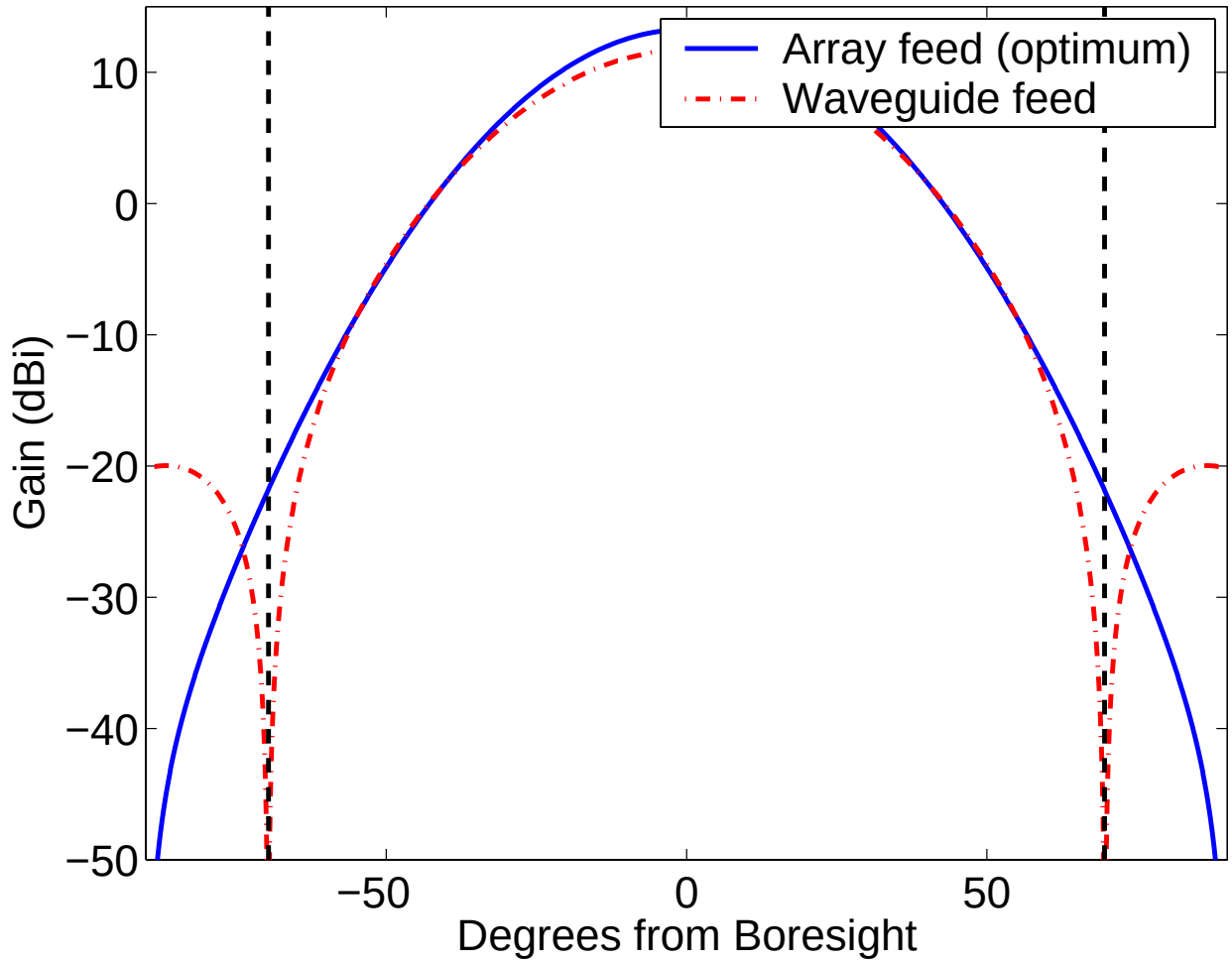


Gain and Spillover Efficiency

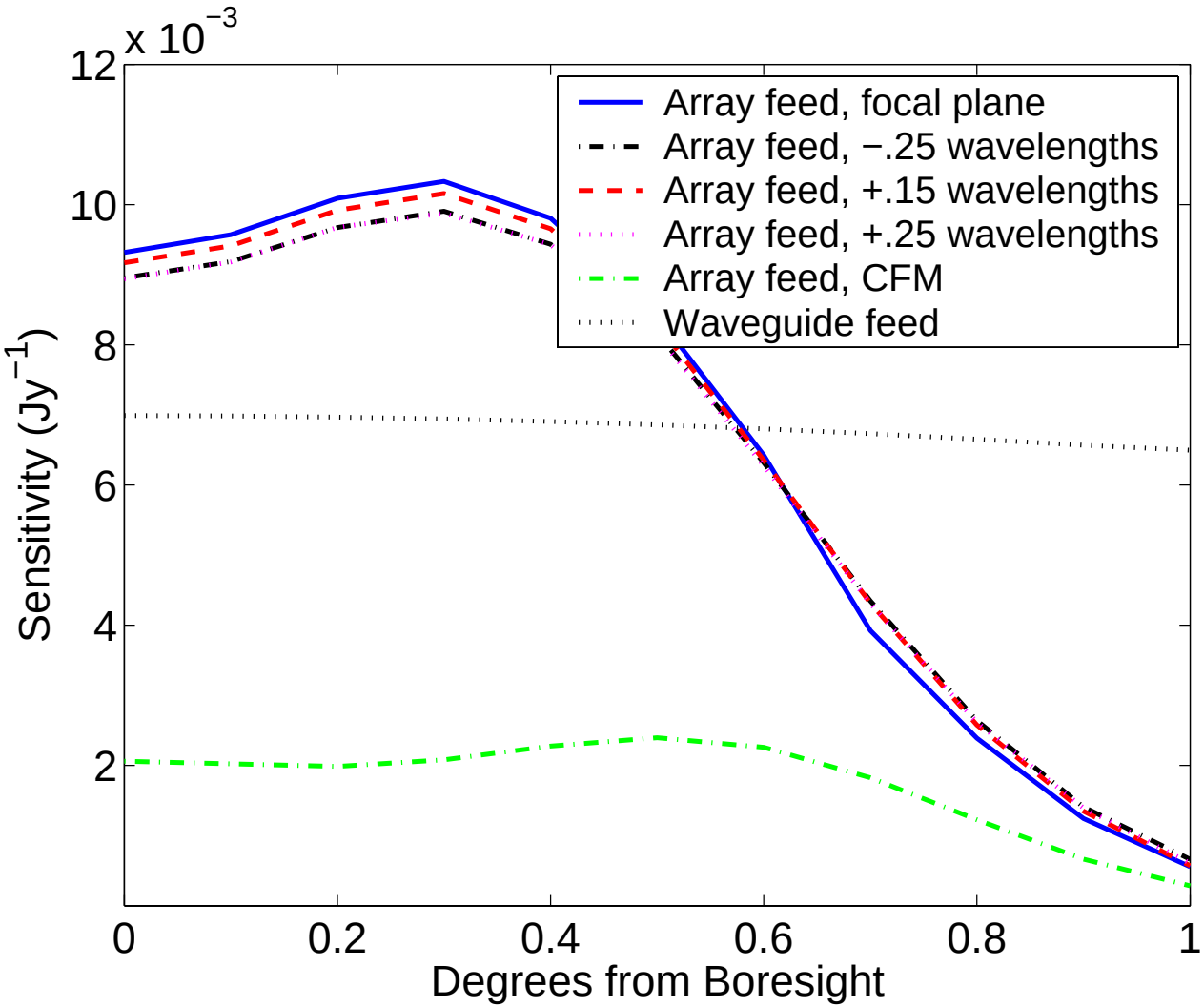




Reflector Illumination Pattern

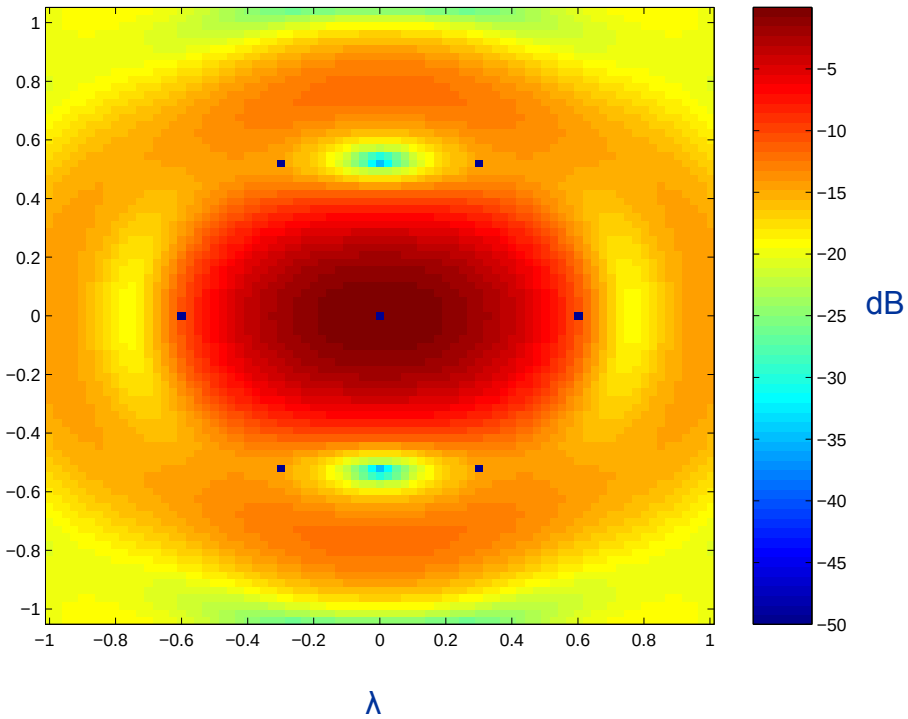


Steered Beams/Offset Feed

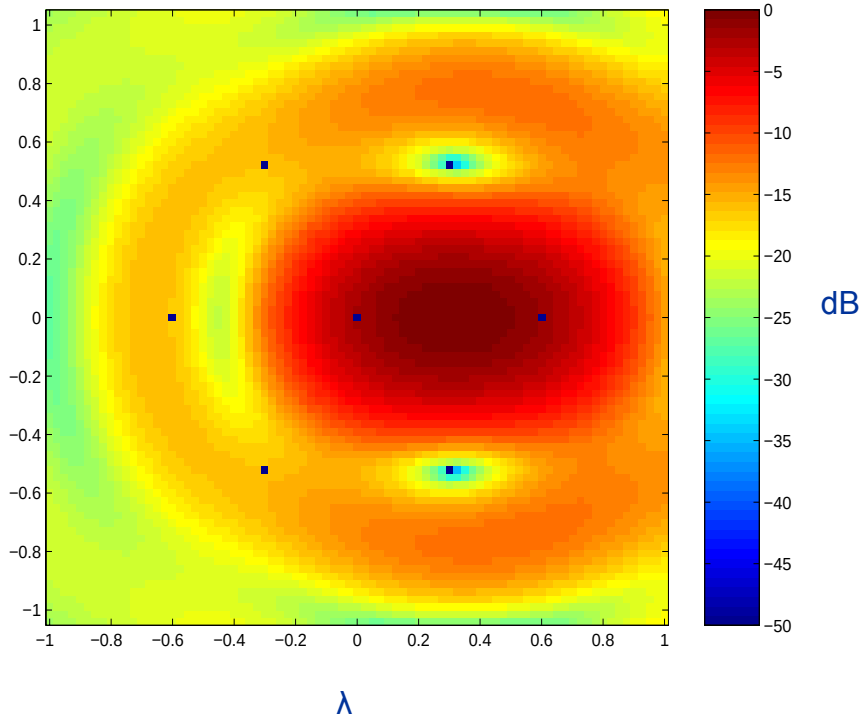


Focal Field Distribution

Boresight

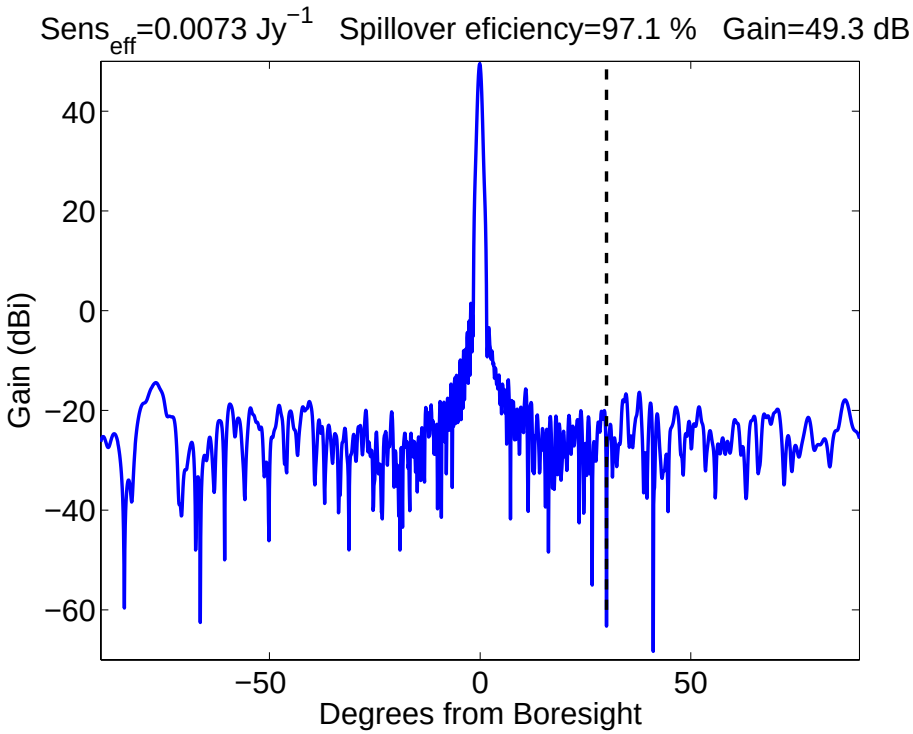


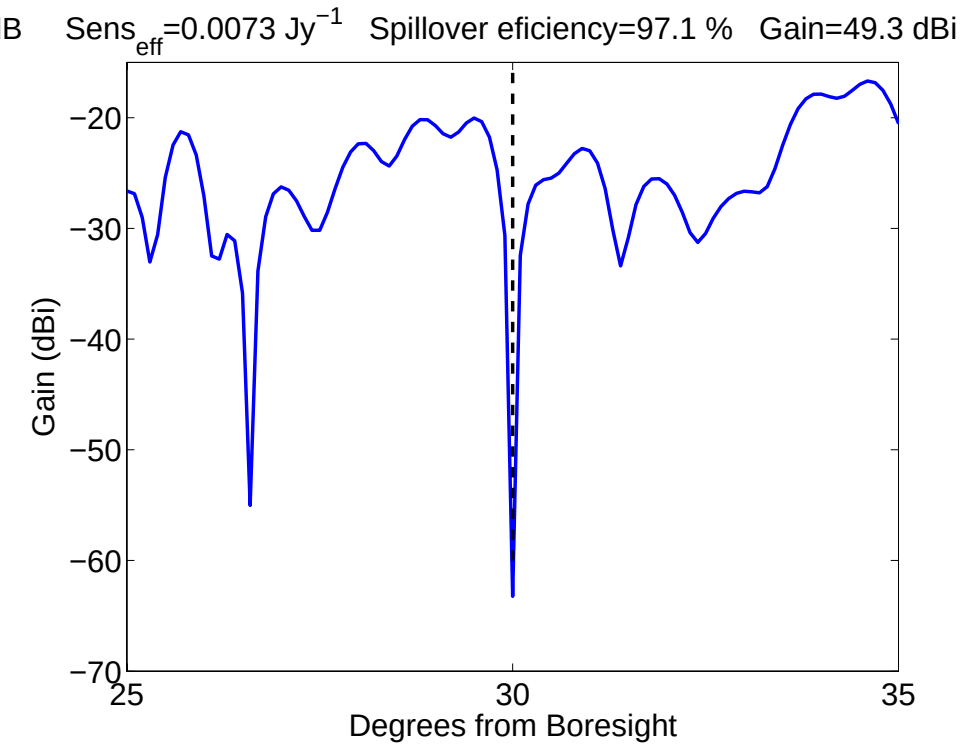
Beam steered to .3˚



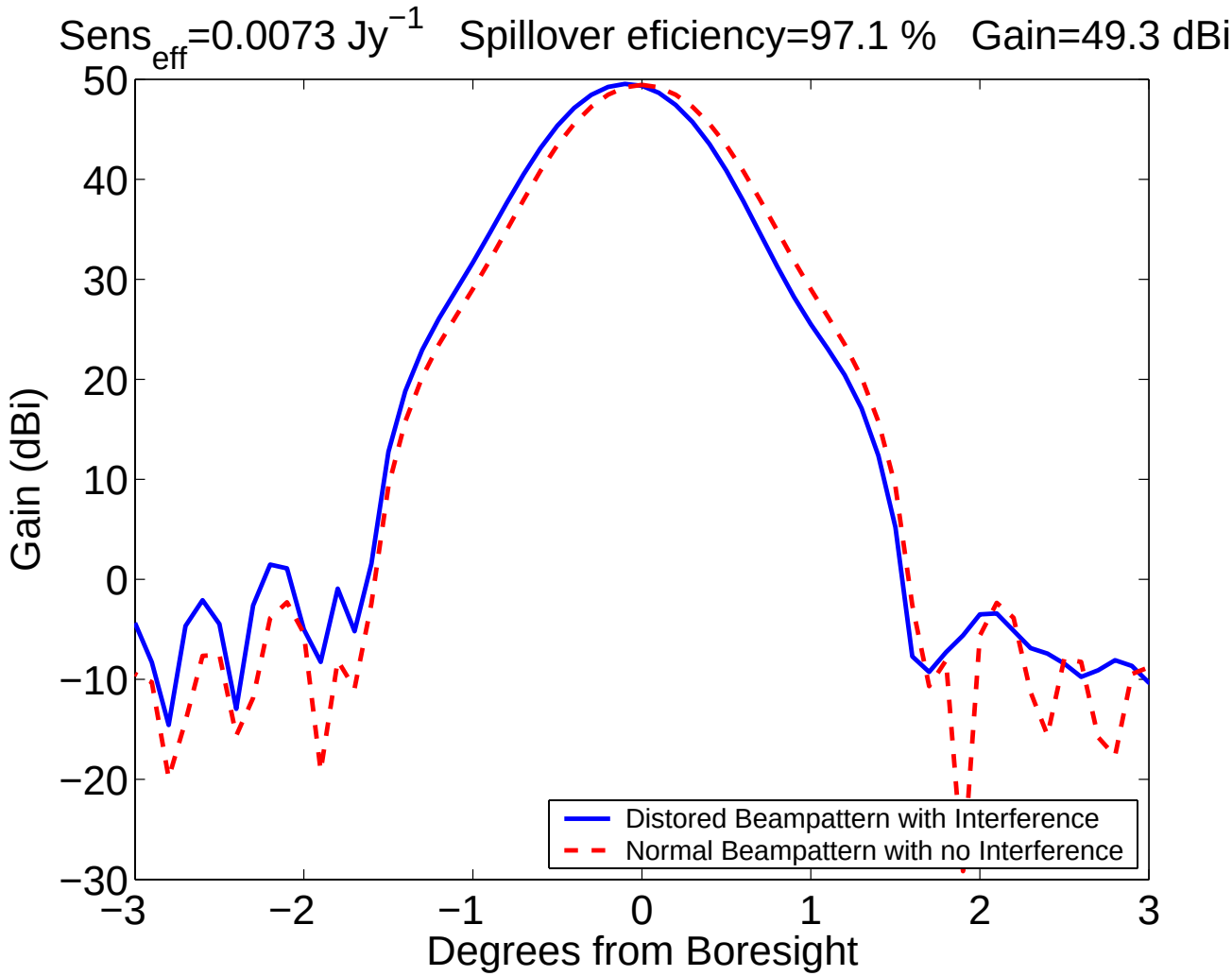
Results (7 Element Array)

Interferer at 30 degrees, INR=0 dB

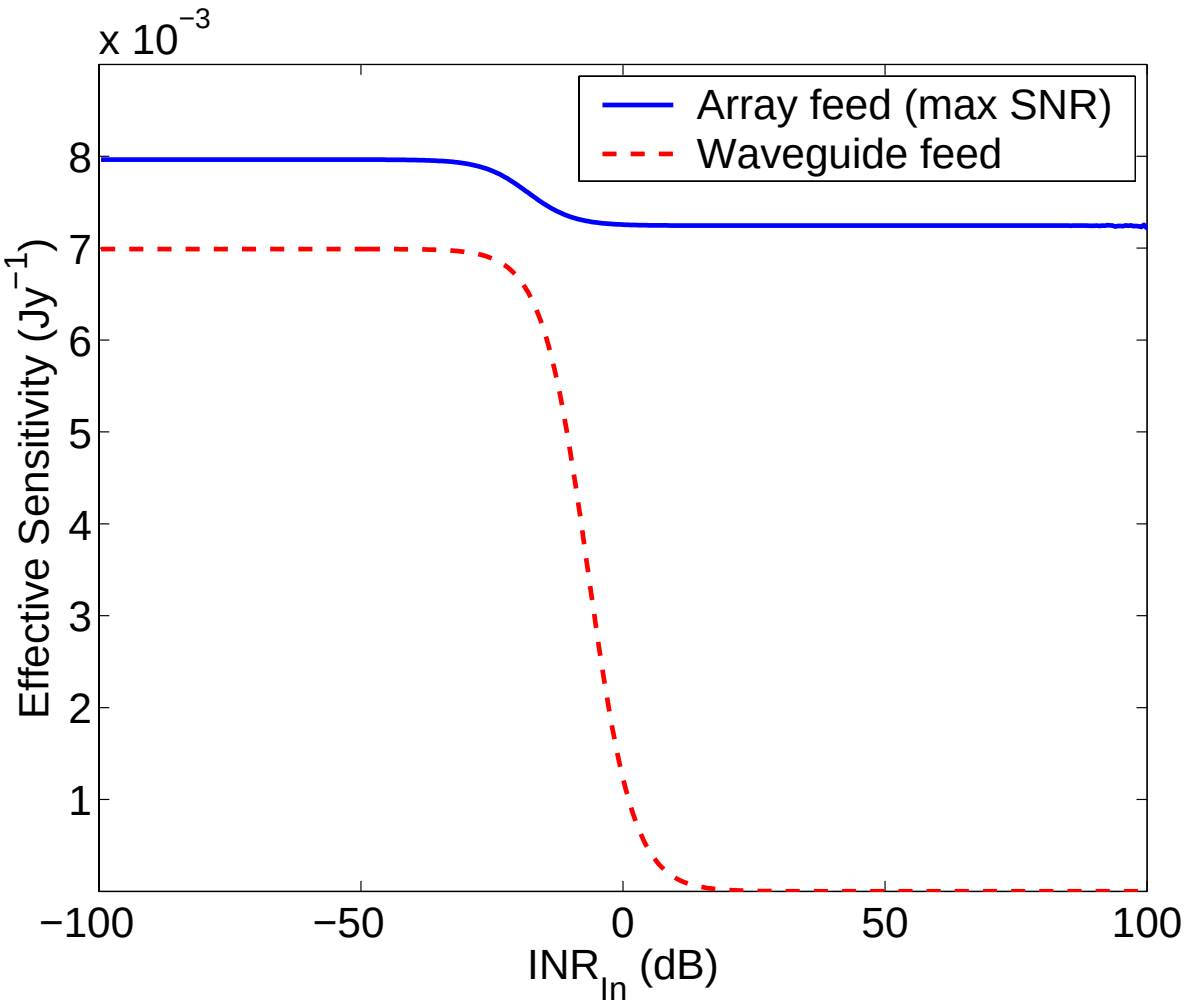




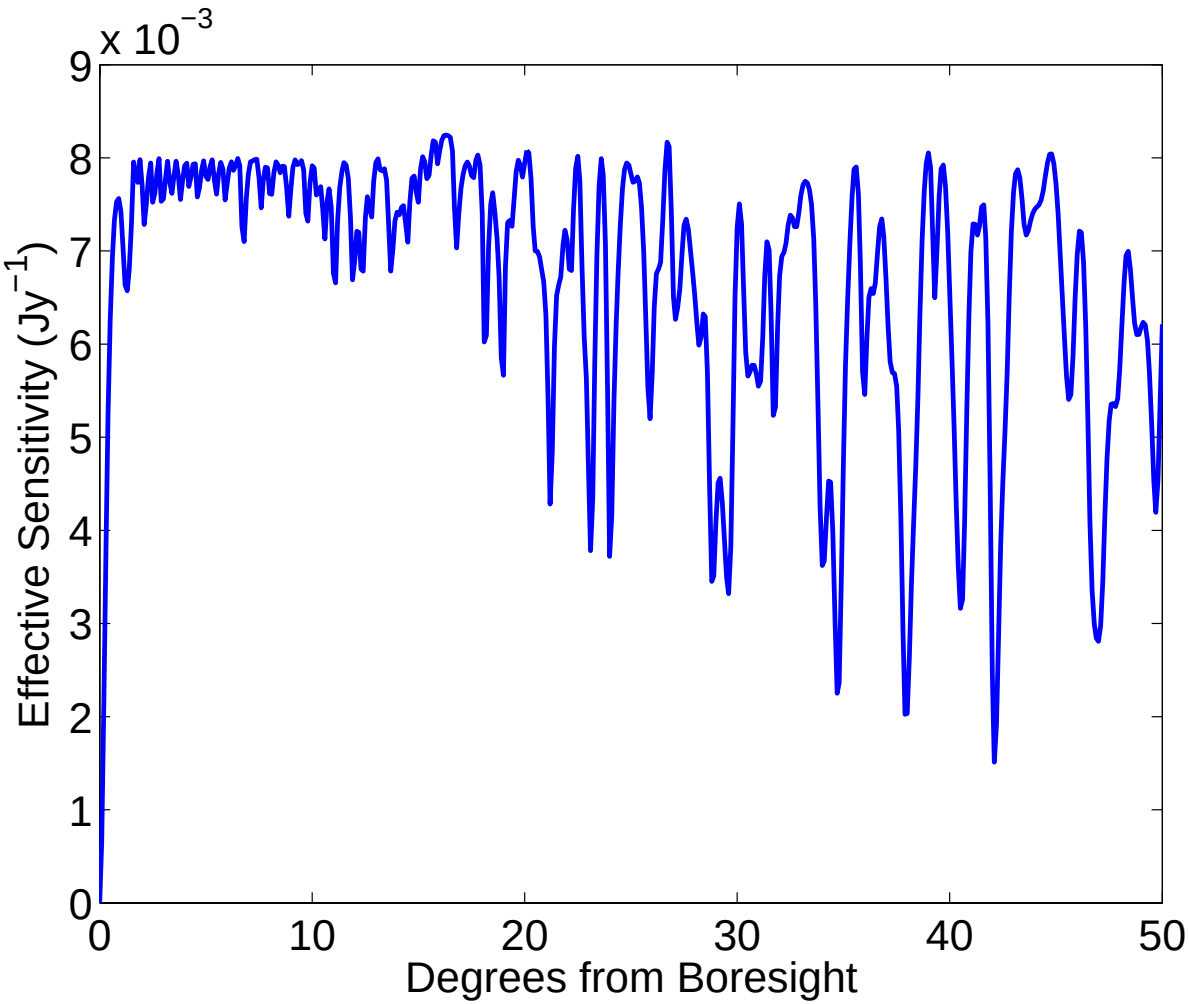
Main Beam Distortion



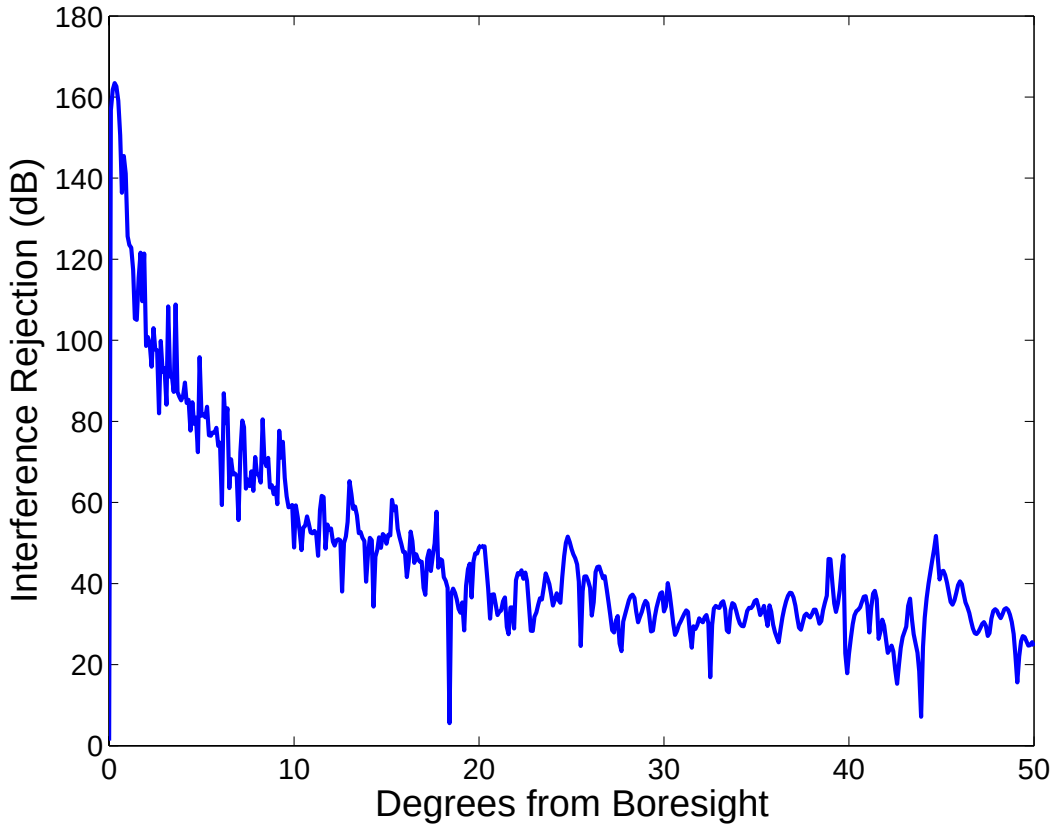
Interferer at 30 deg, INR_{In} changing



Moving Interferer



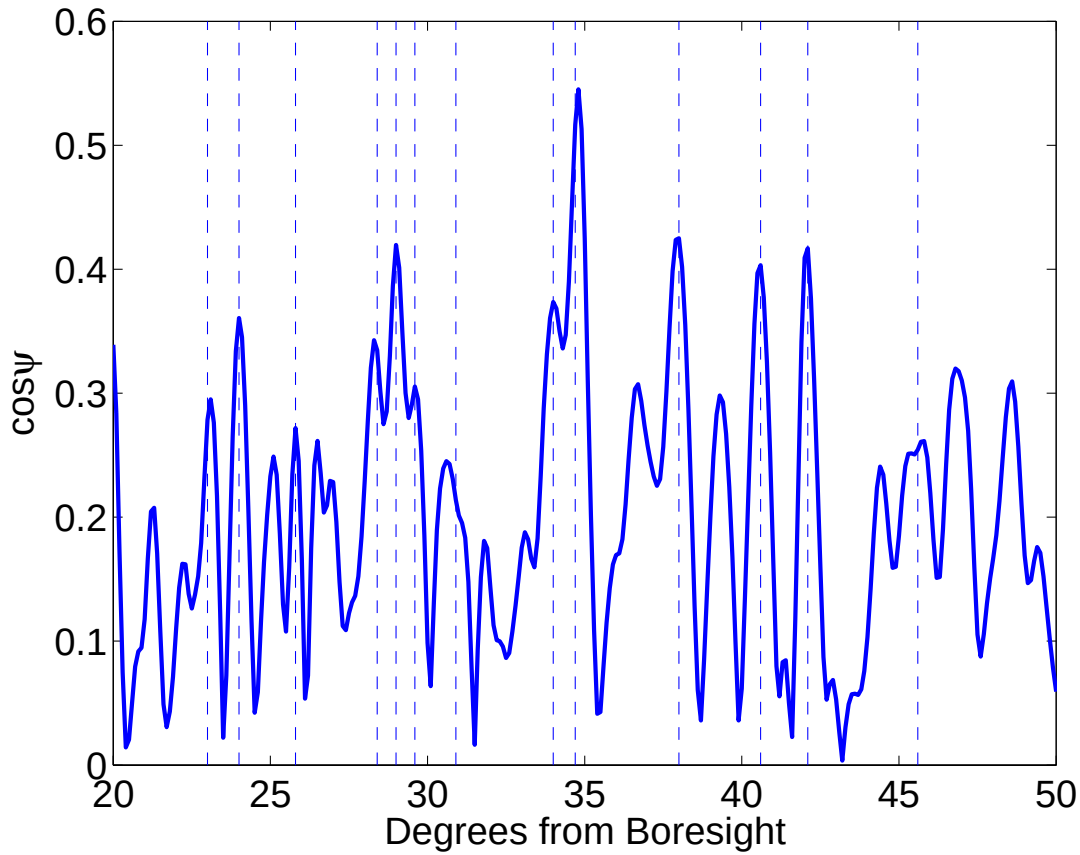
Interference Rejection



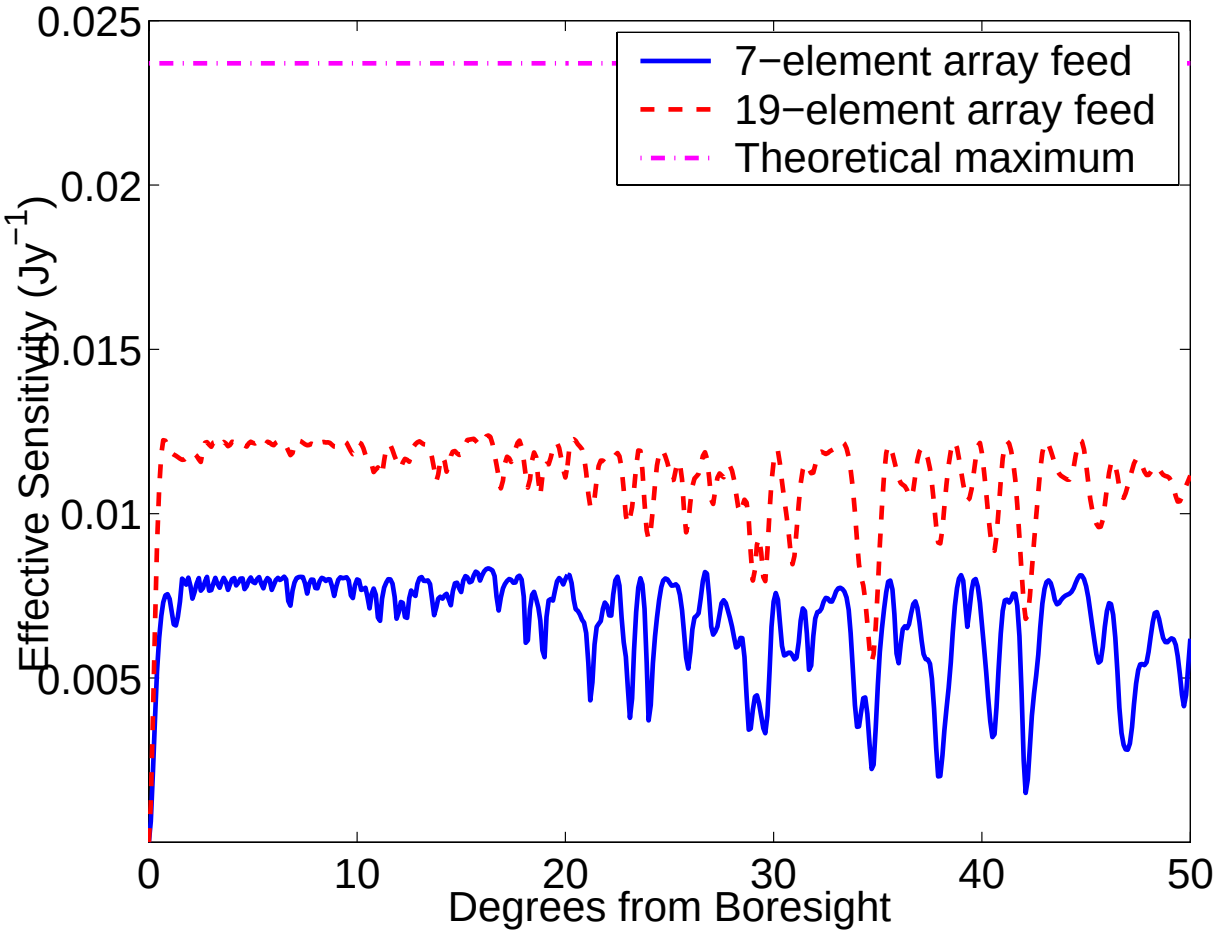
- Low sensitivity corresponds to poor spillover efficiency and gain loss

Signal/Interferer Array Responses

- Angle cosine between interferer and signal response vectors
- Sensitivity decreases when responses are similar
- Sensitivity loss is a grating lobe-like effect



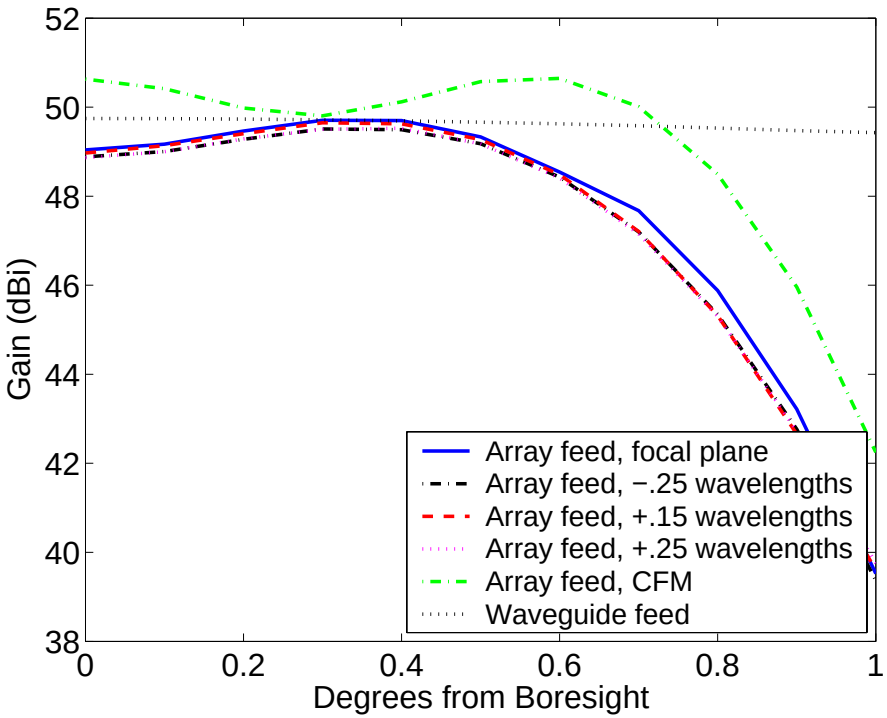
19-element array, moving interferer

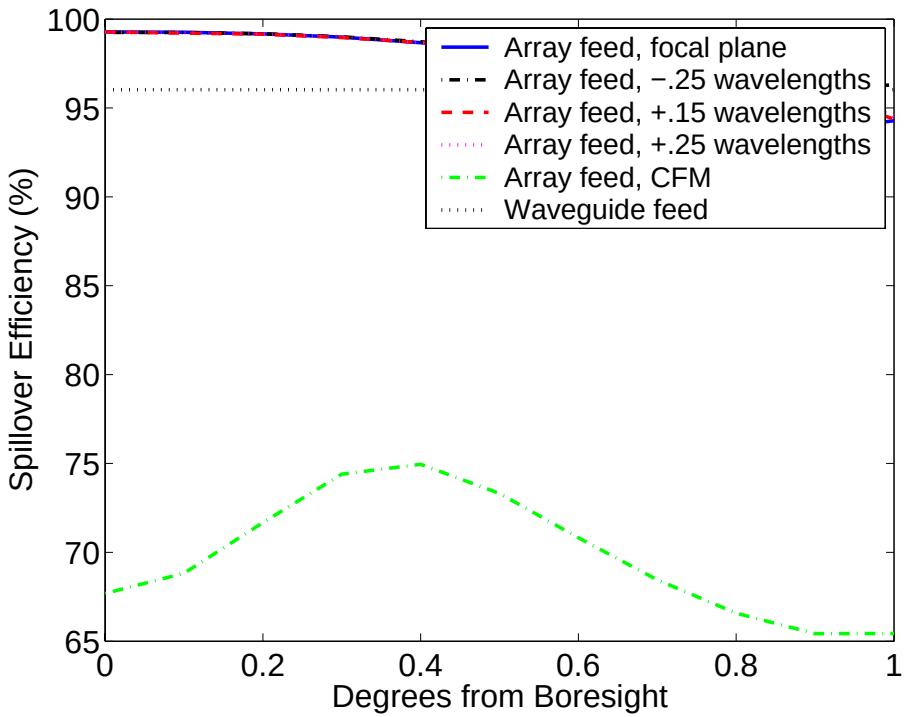


Conclusions

- Good sensitivity can be achieved using an array feed
- In the presence of an interferer
  - Interference at all INR levels and all angles was effectively rejected.
  - Main beam distortion occurs due to beam steering/RFI mitigation
  - Sensitivity fluctuates by a few dB with moving angle of arrival
- Future work:
  - Algorithms: beam shape control, defocusing (larger arrays)?
  - Broadband elements
  - Mutual coupling
  - Prototype…

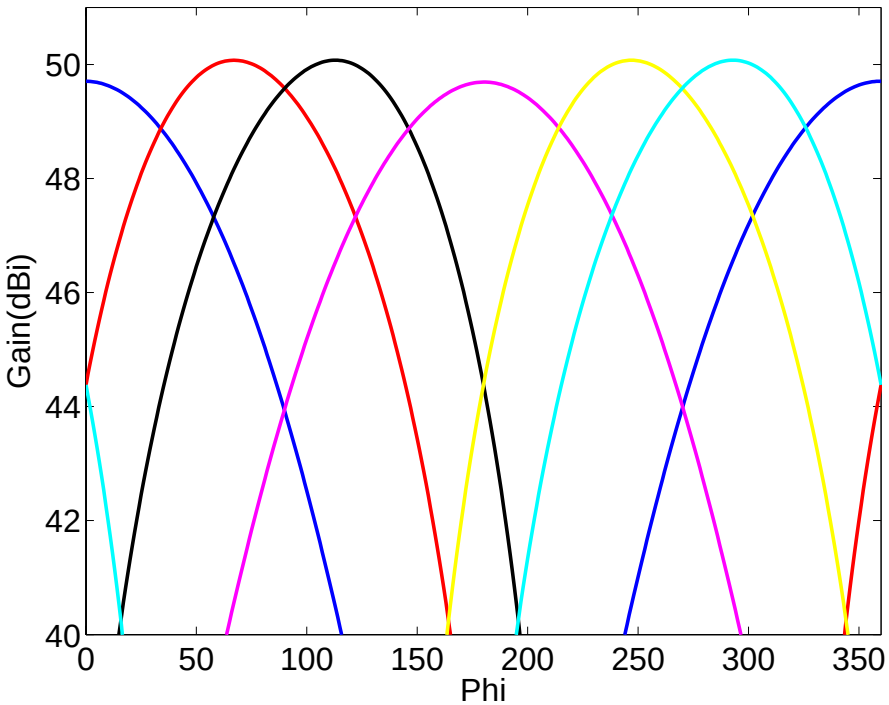
Gain and Spillover Efficiency



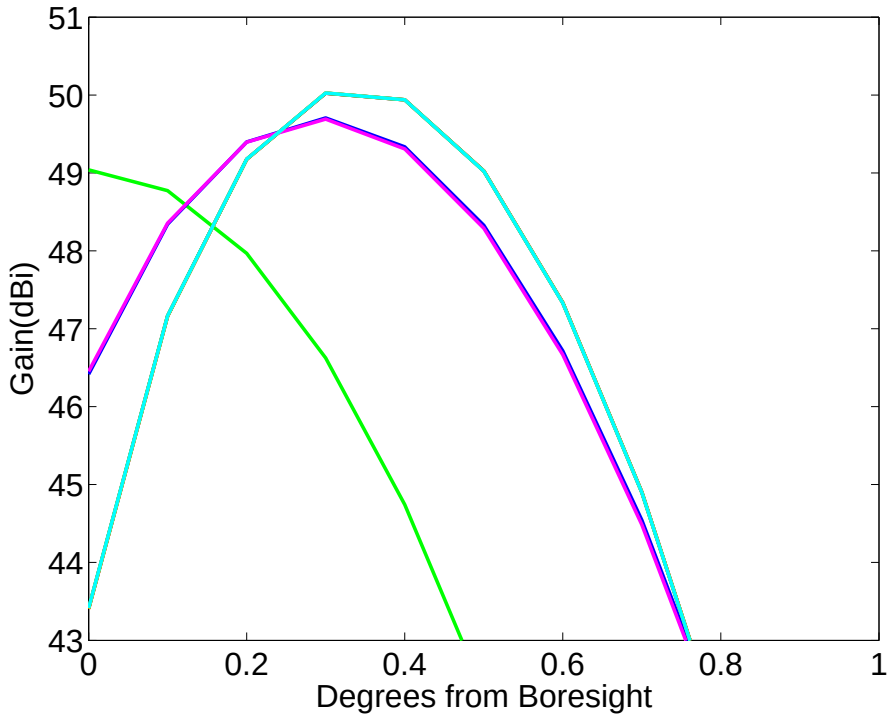


Multiple Beams

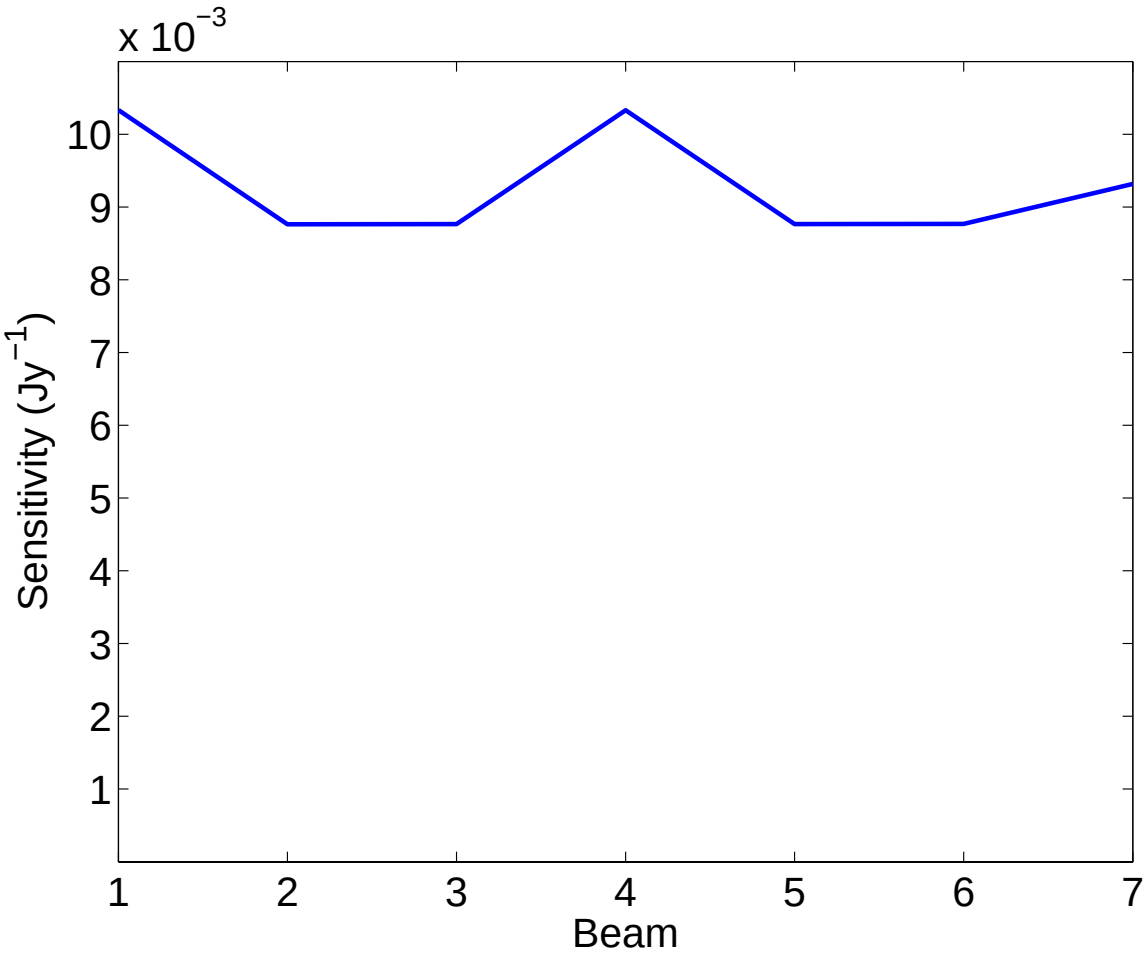
θ=.3˚



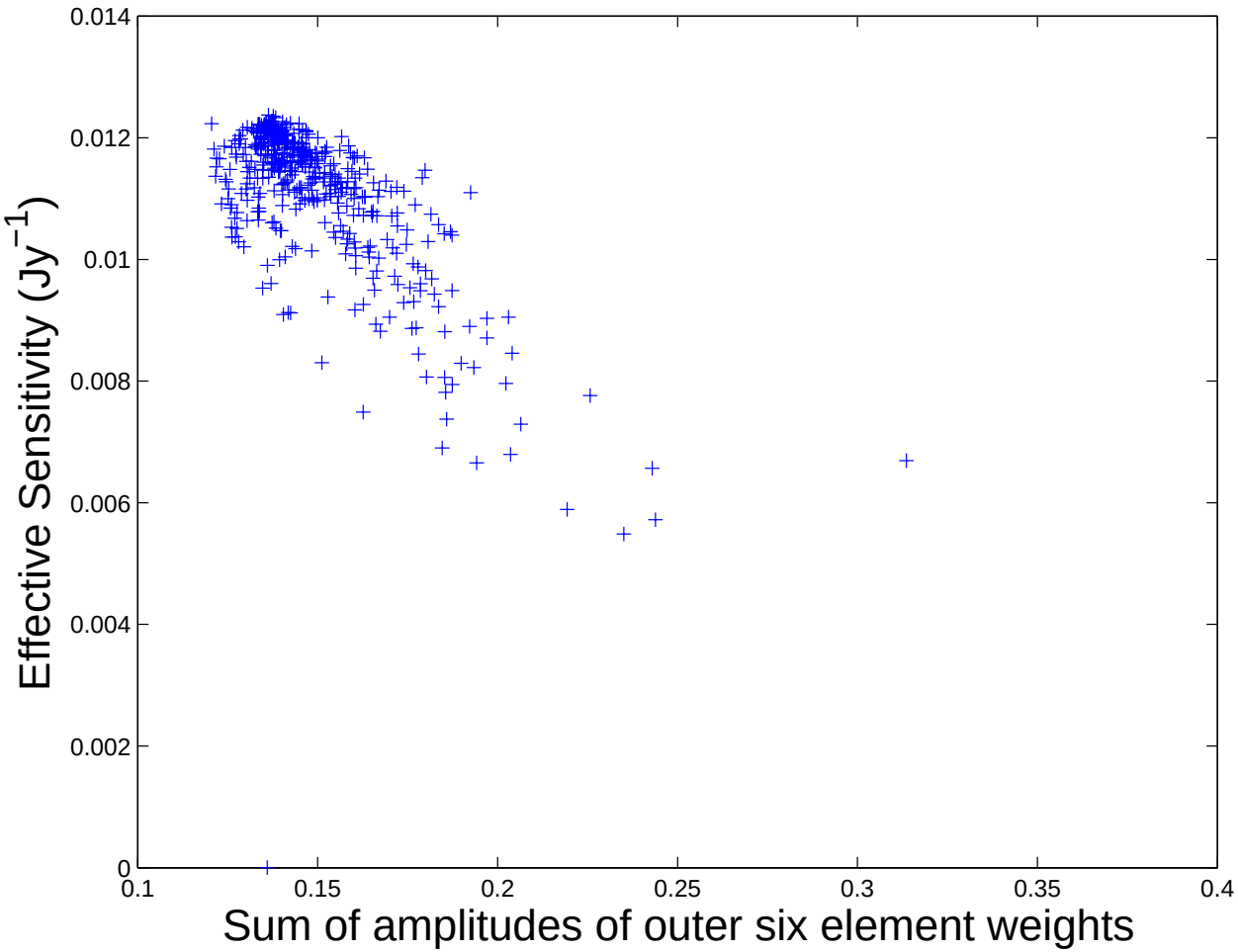
θ-cut



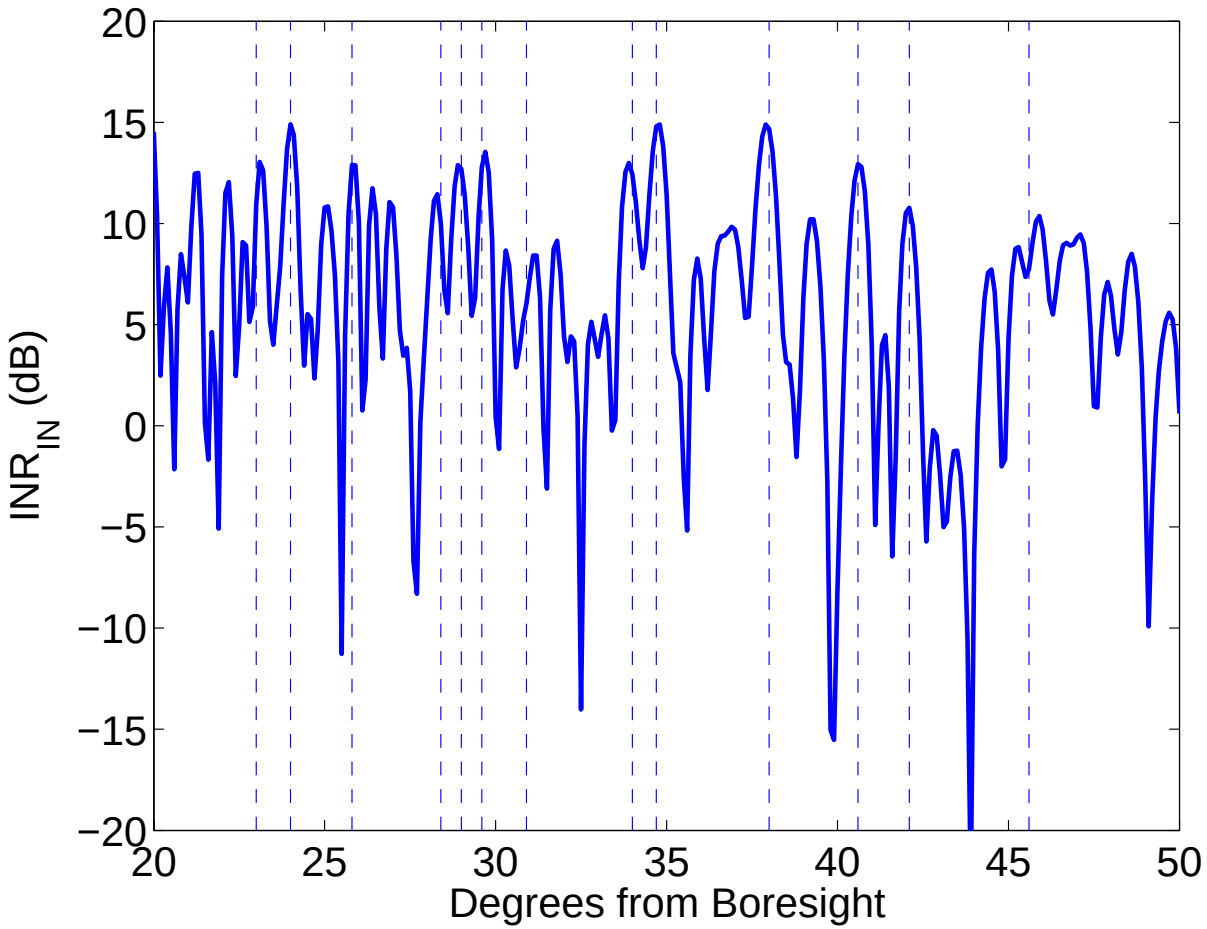
Sensitivity



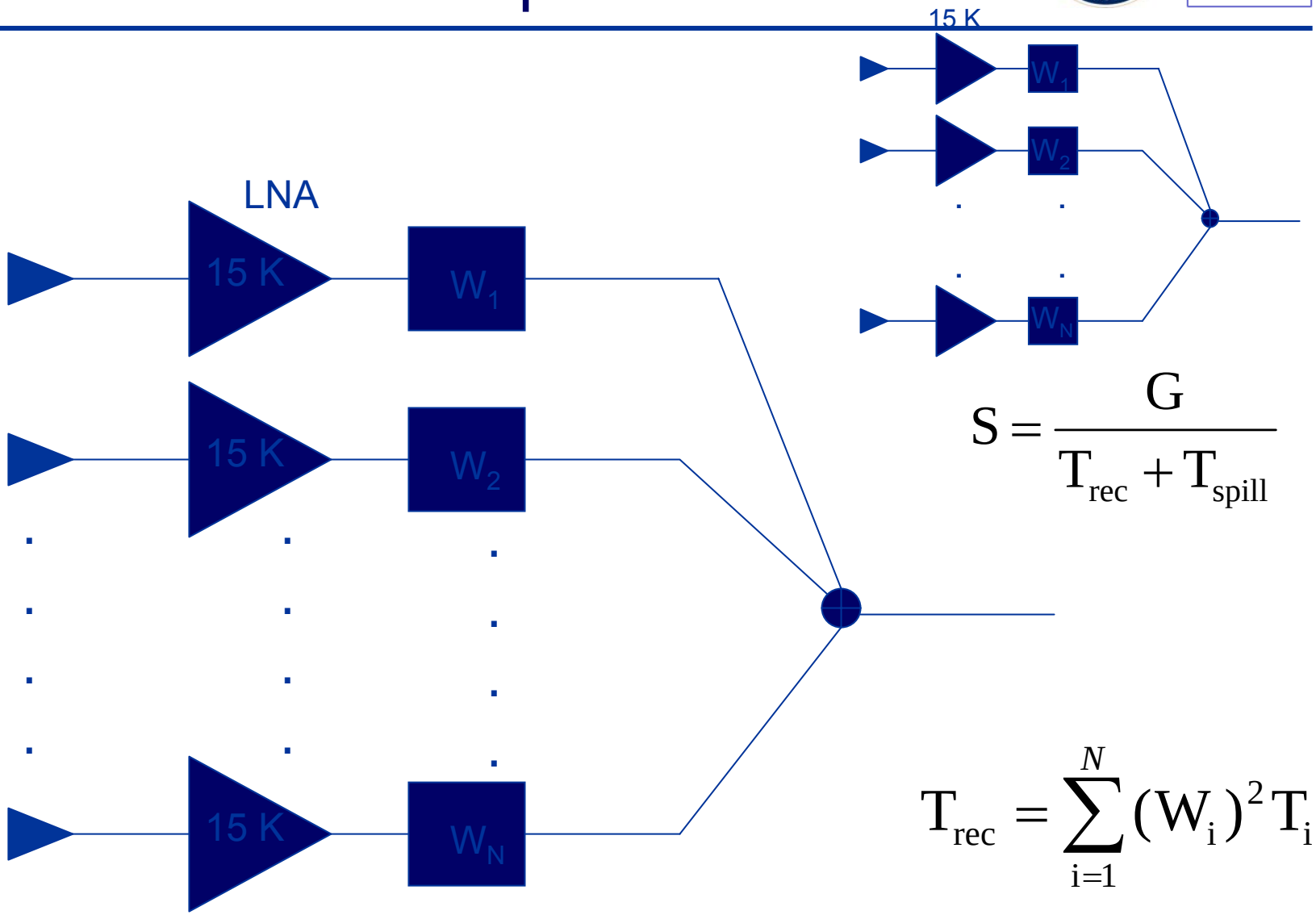
Sum of outer weights



Center element, INR_{IN}



Assumptions



$$S = \frac{G}{T_{rec} + T_{spill}}$$

$$T_{rec} = \sum_{i=1}^{N} (W_i)^2 T_i$$